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EVALUATION OF THE USER REQUIREMENTS PROCESSES FOR NASA TERRESTRIAL APPLICATIONS PROGRAMS

January 31, 1982

Prepared for
Office of Space Science & Applications
National Aeronautics and Space Administration
Headquarters
Washington, D.C. 20546

In Response to
Task Order 48
Contract No. NASW3358

Prepared by
OAO Corporation
7500 Greenway Center
Greenbelt, Maryland 20770

PREFACE

This Report summarizes the results of an independent evaluation conducted by OAO Corporation in 1981 for the Technology Transfer Division of the National Aeronautics and Space Administration (NASA). OAO was asked to review broadly the "user requirements process" employed by NASA for terrestrial remote sensing applications programs. The subject iteslf was recognized as extremely complex, and the evaluation was of limited scope and reiterative through several phases that had special points of focus established by the NASA sponsor. The present Report summarizes the analytical approach used by OAO, and the principal findings and conclusions from the evaluation. Its purpose is to serve as a basis for management review and discussion.

This Report has not been coordinated or reviewed in detail by the NASA sponsor, and therefore does not represent the official views of NASA. Its contents, and the views expressed are the responsibility of the authors: Roland S. Inlow, the principal investigator, and Don L. Olson, associate investigator.

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1.1 THE PROBLEM

In early 1981, the Technology Transfer Division of NASA requested this evaluation to support an ongoing review of questions that were being raised concerning the adequacy of NASA's user requirements process for applications-related terrestrial remote sensing programs. It was recognized that the subject, itself, was complicated, has a long history, and that the extant processes may be as good as it is reasonable to expect. The questions, themselves, were sometimes general, and often seemed to reflect no more than a sense of frustration or general unease with the current approaches. They frequently arose from problems encountered with NASA-user interfaces.

Collectively, the questions reflected a general characterization of the NASA approach to user requirements that had the following elements:

- Ad Hoc. For NASA applications-oriented activities, most "user requirements" are developed, one-time, as part of the support for technical program initiatives. User and technical resources are marshaled to provide requirements inputs to the specific program and then are disbanded. The approach generally involves user-technical interaction through a Study, Task Force, Workshop, Symposium or other one-time mechanism. It is frequently seen as a solution in search of a problem.

- No Follow Up. It is common to regard the user requirements as completed, once stated, partly because the ad hoc groups that developed them no longer have cognizance, and partly because NASA program focus transfers from program initiation to program execution. There are no mechanisms for follow-up, and little accountability.

- Credibility Questioned. The combination of ad hoc initial mechanisms and the absence of follow up, causes the credibility of the original user requirements to be increasingly questioned as time

passes and circumstances change. The authoritative original bases become subject to challenge.

- Participation Not Representative. Selection of persons or organizations to participate in the initial user requirements development activity appears biased to outsiders, and sometimes even to those involved. It is seen as self-serving to specialized user and NASA interests. It is described as an "old-boy" network.

- Varying Methodology. The methods used to develop the user requirements are so different from discipline-to-discipline and from program-to-program, that it is very difficult to make cross-discipline or cross-program comparisons and evaluations, or to aggregate user requirements in support of broader budgetary and executive reviews.

The initial focus of the review was on evaluating the accuracy and significance of the foregoing characterizations. If they were essentially correct, did it matter? To whom? Were there practical alternatives? It was recognized that there were many potential approaches involving different levels of detail and organizational arrangements that might improve the user requirements processes. Some of these, however, overlapped or involved competing objectives. The analytical problem, as defined, was to evaluate issues and alternatives, and attempt to identify steps that would help the evolution of more nearly continuous, systematic, and representative user requirements processes than those employed in the past.

1.2 OBJECTIVES AND SCOPE

The defined objective was to provide support for the evolution of increasingly sound user requirements definition processes that would meet the broad range of NASA's terrestrial applications planning and management needs during the 1980's.

It was decided that the review would be approached through a multi-phased reiterative process focused on key issues; at a modest level of effort; conducted by independent and experienced senior professional personnel. The review was not scoped to be a paper study that would involve extensive

documentation or the large scale of some previous NASA studies. As originally visualized, the evaluation process was to involve close continuing interaction with the NASA Technical Officer and to a lesser degree NASA/OSTA managers. Changes in NASA personnel, organization, and in the scope of the project, resulted in somewhat less regular interaction with NASA managers than planned.

One of the principal perceived benefits of the review was that it would be an independent evaluation by senior, experienced, personnel who were not, themselves, managerially involved in the NASA or user programs. It was anticipated that much of the material developed would be familiar to NASA or user managers. It was hoped, however, that useful insights would emerge from the different focus that the independent review would give to an old and largely intractable subject.

The material was to be developed in as open and frank a process as possible in an effort to give NASA a frank view of itself as seen by others outside the Agency. NASA guidance was that the results should be reported as found, without dilution or concern for the bureaucratic or policy implications. The primary interest was in evaluating the user requirements processes as they functioned in the "real world" at the senior and middle-management levels.

The review was focused more on land remote sensing (represented by Landsat) than on the atmospheric or oceanic disciplines because of the known complexities and issues relating to user requirements for land remote sensing. As a result, the focus was inevitably somewhat more on applications with operational user implications than on purely scientific investigations or one-time experimental/demonstration activities. It was recognized that NASA's role and interaction with "operational" users was, itself a matter of some controversy, but review of that aspect and its implications was one of the objectives of the review.

1.3 METHOD AND APPROACH

The planned approach initially involved four phases of activity.

- Phase I: Take stock, clarify problems and issues, and identify alternative processes that warrant in-depth review;
- Phase II: Develop a plan for the in-depth review of the alternative processes;
- Phase III: In-depth review, development of conclusions and recommendations for management consideration;
- Phase IV: Support management actions on recommendations.

A decision was made during the project to limit the activity to the first three phases, with a somewhat reduced scope. A separate review and presentation of findings was made at the end of Phase II, taking account of data developed to that point. The present Report summarizes the overall activities and findings.

The flow of the analysis and general method are shown in Figure 1.

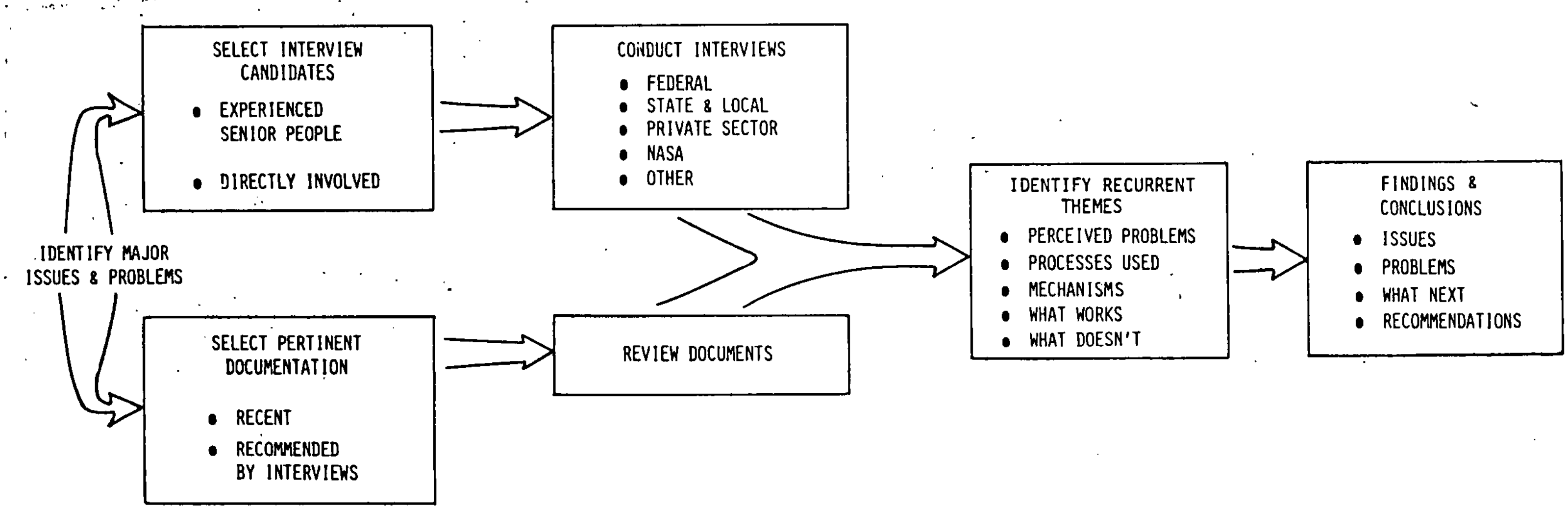
As the figure shows, the initial step involved review of the issues and problems associated with the user requirements processes as characterized above. The next steps involved selection of persons to be interviewed, with the criteria that they be senior experienced people directly involved with the NASA processes. Selection of additional people for interview during the course of the review was a continuing activity based on information and findings as developed. Documents were selected for review on the basis of pertinence, or as recommended by those interviewed.

A principal source of data was interviews with knowledgeable people. During the course of the overall evaluation, about 70 detailed interviews/discussions, lasting 3-4 hours each, were held with experienced mid-to-senior-level managers who were directly involved in day-to-day uses, or planning for the uses, of data from NASA remote sensing systems. A decision was made early in the project to emphasize in-depth interviews with a

USER REQUIREMENTS PROCESS

FIGURE 1

FLOW AND APPROACH TO THE EVALUATION



limited number of people rather than larger numbers of shallower discussions. Personnel were selected to represent interests and knowledge from a range of organizations, internal and external to NASA, at different stages of the user requirements development process.

Detailed notes were made during the interview, for use by the authors. To promote openness and frankness, the discussions were held with the understanding that the views expressed would not be attributed to the individuals, although most indicated that they were quite willing to be quoted. A number of additional, but less extensive, discussions were held on the subject with other individuals who are involved in various aspects of the user requirements process. The selection of interviews was not designed to be a statistically representative sample of NASA and user personnel. It was designed to be practical, in the sense that all of the persons interviewed were experienced mid-to senior-level people who were directly involved with NASA remote sensing activities or with the satisfaction of major user needs. It was judged that their views, collectively, together with document reviews, guidance from the NASA Technical Officer, and other discussions, would be sufficient to illuminate the issues.

Two subject areas, geologic mapping and domestic crop production reporting, were selected for examination in greater depth than others during Phase III of the evaluation. They were chosen, with the guidance of NASA managers, as illustrative of important subjects that have involved a range of interaction with NASA remote sensing programs over a number of years, and reflect the different interests, problems and breadth of considerations involved in the management of the user requirements processes. About 40 of our in-depth interviews were with senior-and middle-level managers in the geology and agricultural fields and we developed large amounts of detailed data from the interviews and related document reviews. These data are much too detailed for presentation in a summary report but provide an important base for a number of our judgments. Some selected observations on these subjects are provided in an appendix.

Throughout the evaluation we attempted to identify the recurrent themes in terms of the perceived problems, the processes used to develop and manage

requirements, the mechanisms employed, and finally, a frank understanding of what works, and what doesn't.

From the foregoing data, we attempted to develop findings and conclusions that focused on the issues raised, the problems that are encountered, an assessment of the future outlook, and our recommendations.

1.3.1 Topic Complexity

At every level, there is a recognition that the topic "user requirements process" is inherently complex.

- Definitional - The terms, themselves, mean many things to many people and may be defined quite differently depending on the discipline or group involved.

- Diverse User Communities - There are literally thousands of individual users of NASA-originated remote sensing data, world-wide, and hundreds of scientific investigations in progress. User communities for the different disciplines vary significantly in scale, location, and homogeneity.

- Diverse Stages - Different users are in vastly different stages of evolution in their levels of understanding of remote sensing possibilities, and in the maturity and sophistication of their analyses. These range from basic scientific research on the one hand, to support of "operational" decisionmaking on the other. Some regimes (e.g., meteorology) have had many years of spaceborne application, while others (e.g. oceanic) are still in their infancy.

- Varied Disciplines and Applications - Each discipline, and applications within disciplines, generally have unique attributes not present in others. The variety of potentially fruitful research or applications involving remote sensing, in detail, are almost limitless.

- Embodied Problems - The combination of the different institutional settings, the planning process, management practices,

priorities, national policies, etc., present a difficult environment in which to develop user requirements.

- o Remote Sensing Role - The utility of space-borne civil remote sensing is in many cases complementary to data derived from other more conventional sources. Measuring the marginal utility of remote sensing is a formidable problem.

1.3.2 Definitions

There are many types and levels of "requirements" and there were widely varying views on how "user requirements" should be defined, including for the present review. There was almost universal agreement that, today, the terms mean many different things to many people, and that it would be valuable to have commonly agreed understandings. Toward one end of the spectrum there are design specifications ("requirements") that are used to guide the processes of technical design and construction of remote sensing instruments and systems. At the other end there are user information needs ("requirements") that are the user-oriented bases for technical action in the first place. There are many levels of detail and different points of focus along the entire requirements spectrum, with different emphasis by different participants and organizations.

There was also the continuing question of whether "requirements" should be considered to be independent of the technical capabilities to meet them. There was no common view on this aspect, but it had a major bearing on the way some participants viewed the processes, roles, and so on.

For evaluation of the user requirements process, a working definition of terms was developed, as follows:

- o User - Person or organization responsible for decisions or assessments based in whole, or in part, on information acquired from remote sensing.

- o User Requirement: Statement of the information needed by a user, and associated availability criteria.

- User Requirements Process - The combined steps taken to identify users, define their information needs, and effect the translation of these into specifications and characteristics that define the response to the needs that is feasible through the employment of spaceborne remote sensing technology.

- Mechanisms - Methods of handling and managing the interactions necessary for the process to function.

1.3.3 Organization of the Report

The following sections of the Report have been organized to present a distillation of the extensive data and wide variety of views that we encountered during the evaluation, together with our own observations developed from all of the data we examined. With a topic of this complexity and known diversity of views, we recognize that our selection of material will inevitably seem incomplete and represent support for some views and a slighting of others. We have not attempted to evaluate them as "right" or "wrong", but rather as examples of viewpoints that NASA and user managers held, and felt were of sufficient importance to air in relation to this topic. The Report is intended as a basis for discussion and management consideration. The sequence of the Report is outlined briefly below.

In Section 2, we review the Elements of the Problem under the following headings:

- 2.1, Institutional Setting, discusses some of the differences in institutional arrangements and outlook between NASA and users that affect the development and management of user requirements data.

- 2.2, Stages in the Process, discusses the variety of stages and data content that are involved in the full span of the processes from identification of user information needs on one end, to the design and operation of a technical response to those needs, at the other end. Discipline differences are discussed.

- 2.3, User Communities, discusses some of the problems encountered in identifying "users" in a consistent fashion, both individually

and collectively, together with factors that affect NASA-user interaction. A distinction is made between "uses" and "users."

- 2.4, Processes and Mechanisms for Interaction, presents some of the views that were encountered concerning the applicability and usefulness of the wide variety of processes and mechanisms that are available. What works, what doesn't.

- 2.5, Strengths and Weaknesses, discusses the most frequently cited strengths and weaknesses in NASA's approach to the user requirements process.

In Section 3, we draw upon the material reviewed in Section 2, and provide an evaluation in the following context:

- An Alternative Mechanisms section (3.1) discusses a number of proposals that were made for the user requirements processes and the special points of emphasis that proponents advanced. These are evaluated.

- An Elements of An Optimum Process section (3.2) summarizes the common elements and necessary conditions that need to be combined in evolving an optimum user requirements process.

- A Conclusions and Issues section (3.3) presents several general conclusions and identifies some of the issues that appear to be central to the question of improving the effectiveness of the user requirements processes.

- A final section (3.4) presents Recommendations.

The Appendix presents some selected observations and data from our review of geologic mapping and domestic crop production reporting programs.

2.0 ELEMENTS OF THE PROBLEM

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2.1 INSTITUTIONAL SETTING

The institutional setting has a major bearing on the process of identifying and developing user requirements data. The differences in the setting need to be taken into account and accommodated for the user requirements definition process to be effective.

2.1.1 Federal Sector

In the federal sector, there is an institutional mis-match between NASA's research orientation and related approaches to program definition and problem solving, and the approaches of "old line" Departments like Agriculture and Interior. These Departments and others at the same time, have had major user interests in a number of NASA remote sensing programs.

- The large Federal Departments consist of semi-autonomous Bureaus or Agencies that perform specialized functions, which are generally long-standing and legislatively mandated. The programs of these agencies have their own complex histories. They generally rely on conventional information sources and data gathering methods that have evolved over many years and are embedded firmly in the outlook and practices of these agencies. Old line agencies also have well established and strongly supportive constituencies that rally behind them when programs are challenged. Improvements via space remote sensing or innovative techniques are welcomed <u>if</u> they are proven reliable, and cost-effective, but there is little independent incentive to take risky initiatives. As one manager put it, "no chief will have programs live or die on the basis of uncertain technology and program continuity. . . he will stand pat."

- NASA, on the other hand, is a young agency without long-standing functions, or established constituencies like those of the Departments of Agriculture and Interior. Compared with the old line agencies, NASA's science- or applications-oriented programs

are more variable from year-to-year, need more continuing justification, and frequently are higher visibility, risky endeavors. All agencies, however, are sensitive to criticism, and this causes even old line agencies to be open to new approaches and technology, if they prove feasible and are reliable.

- o NASA has more elaborately structured external processes for reviewing and evaluating programs than those used by old-line agencies. NASA, for example, has the variety of advisory groups that meet periodically. These range from an Agency-wide advisory Council, to specialized Advisory Committees and Subcommittees in specialized discipline areas, as well as Technical Review Committees for oversight of technical approaches. There are few counterparts of these bodies in old line agencies.

- o Many old line agency programs just "go", on the basis of legislative mandate or long standing practice. The annual justification for these programs is rarely questioned in a fundamental way.

The differences in basic orientation between NASA and old line agencies affect their approach to "user requirements".

- o NASA is characterized as having engineers/scientists who look at user requirements like a moon shot: Objectives are defined; a fixed schedule is set; the requirements, once stated, do not change. The NASA orientation is to know concretely what is to be done before starting, with "requirements" tailored to technical capabilities, and the over-all program is one of executing. "Success" consists of designing, building, and operating the technical apparatus.

- o Old line agencies, on the other hand, are characterized as having frequently changing user requirements. The "real" requirements come from people responsible for making decisions. Their information needs are rarely ever fully satisfied, and new techniques or sources of information are judged valuable even when the improvements are small. Whether technical capabilities exist to

address the information needs is incidental to the statement of a requirement.

- What seem to others to be small incremental improvements in data development capabilities, therefore, often have sufficient value to old line agencies to warrant support and action. NASA programs, on the other hand, tend to be driven toward bigger and more glamorous objectives because of the demands of the program justification and budgeting cycle.

In the applications area, NASA "has gotten over the major learning period with self-initiated projects. There are fewer and fewer areas of applications-related research that are brand new, glamorous, and subject to broad executive and congressional support." The absence of an authoritative user requirements process handicaps the development of program support. Its research activities are viewed by many as being carried out for research's sake, and the application is the carrot on the stick.

- The problem that these circumstances creates is "how to plan in NASA when there is no certainty that other agencies are planning to use the output 5 to 7 years hence after NASA development or demonstration is completed." Other agencies, on the other hand, are reluctant to commit resources because of uncertainty about the continuity and long run viability of the NASA remote sensing programs. There is no market mechanism.

One of the main challenges of the user requirements process lies in the fragmentation of missions and responsibilities among the Federal Government agencies that comprise, overall, the biggest user market. The situation is compounded by fragmentation within NASA. Under these circumstances the user requirements process is continually plagued with the problem of attempting to provide concrete linkages between interests that are ambiguously defined, and the result is uncertainty and inefficiency on both sides of the interface.

- Fragmentation throughout the Federal Government is regarded by some as the major cause of difficulty in attacking the NASA/user interface. There is an absence of specific goals related to

remote sensing. There are no recognized spokespersons on many issues and subjects. In their absence, there is a vacuum for which no one feels responsible.

- The fundamental need for requirements definition is at the highest levels of management where the highest level planning should take place, and where major decisions get made. Unfortunately, it is very difficult to obtain support for long range space applications from the highest levels in user agencies. The highest levels are short-assignment political appointees, with generally limited professional expertise, and with many competing interests for attention.

2.1.2 Private Sector

There are pronounced differences in the institutional setting of NASA and the private sector. These differences affect their outlook on the process of requirements definition, and on what the goals of the process should be. From the private sector viewpoint, no NASA research program (except for basic scientific research) should be undertaken without an ultimate operational user's needs specifically in mind. Remote sensing is simply another means to specific ends. In this view, a user requirements process must deal with the remote sensing system end-to-end, and consider the needs of both "operational" and "research" users. NASA has traditionally concentrated on the latter at the expense of the former.

- It makes a lot of difference, for example, if "user requirements" equals a scientific "wish list" or equals legislatively-mandated information needs that the responsible agency must meet. . .or something in between.

- From the private point of view, the ground rules should be that a "requirement" hasn't been defined until a user has been identified who is willing to pay for the eventual product.

Industry has to define requirements very carefully because the governing element is the ability to pay and have a quick return on investment (two to four years). The Government is poorest in this respect because ability to

pay doesn't come into play in the way it does in commercial activities. The Government is also "generally poor at marketing, because it has no concrete incentive to develop a market, selling and evolving products."

- A private owner would have to have end-to-end control to deliver specific products against contracts, or go out of business.

- The Government does not go out of business if it fails to deliver. In many instances it provides its services/products without charge.

NASA has a legislated mandate for research, but, in the private view, all such research (except basic) should be connected with a potential operational user's demand.

- The expensiveness of space systems is such that the Government must lead in identifying its own needs for remote sensing products. But, there are very few people in Government who even think about those needs. There is little authoritative consolidated data on what the Government is required to do by law and the related remote sensing data needs.

If a corporation were the owner/operator of the civil land remote sensing system, for example, its life blood would be in determining user needs (requirements) and selling responsive products to customers. The primary point with regard to user requirements is that NASA and private commercial users view information needs (requirements) and the potential utility of space borne remote sensing from very different initial perspectives and interests. NASA's is much more open-ended, while the private sector is qualitative and market oriented. Interaction requires special arrangements on both sides of the interface.

2.1.3 Scientific - Academic Sector

NASA's institutional setting and practices most closely approximate those of the scientific -academic sector. NASA's basic charter is to conduct space related research. The "users" of many NASA remote sensing program outputs, for years, have largely been scientists. The programs have been research-oriented, aimed at improving basic knowledge, or developing the

means of improving it. Even when NASA has acted as a contractor for operational systems, such as NOAA's meteorological satellites, its focus has been on developing the technology for improved sensing and understanding basic phenomena.

Many of the scientific users of NASA's research output are supported by NASA funding, and there are common and closely-knit user communities that involve the interaction of small numbers of key scientists and NASA personnel, on individual projects or investigations. In general, there is close, continuing interaction through various scientifc advisory bodies and the mechanisms of the scientific community at large.

2.2 STAGES IN THE PROCESS

There are two generally accepted ways to approach the formulation of user requirements for remote sensing:

- o What information is extractable from remote sensing?
- o What problems need solving?

From either direction, when carried to their conclusion, these approaches should arrive at the same point. NASA typically starts from the first direction, users from the second.

There are, in turn, a specific set of stages that are involved in the requirements definition process, regardless of the starting point, the specific subject, or whether a scientific investigation or broader user application is involved:

- o Identify the user problem
- o Identify the information required to solve the problem
- o Specify the data required to produce the information (accuracy, scale, format, type...)
- o Specify the measurements required to produce the data (spatial resolution, spectral resolution . . .)

- o Identify and evaluate technological approaches to providing the measurements, including remote sensing

The contents of each stage differ significantly in internal detail, depending on the discipline and type of application, and the process of translating from one stage to the next involves the use of a model(s) that relates the adjoining stages to each other. Overall, there are several orders of models involved in the stage-to-stage translation process.

3.2.1 General Structure

It is very important to identify systematically the stages involved in the "user requirements process." In practice, it is difficult for personnel working on specific detailed aspects, to have perspective or competence on the entire process. A major problem, for example, is that most users cannot state requirements in terms of remote sensing measurement values needed, but only in terms of information needs. As a result, it does not make sense as is often done, to ask them to express their requirements in terms of spatial resolution, spectral bands, etc. needed. They really do not know. Sometimes they do not know that they do not know. "Users should be asked to concentrate on defining their data needs.

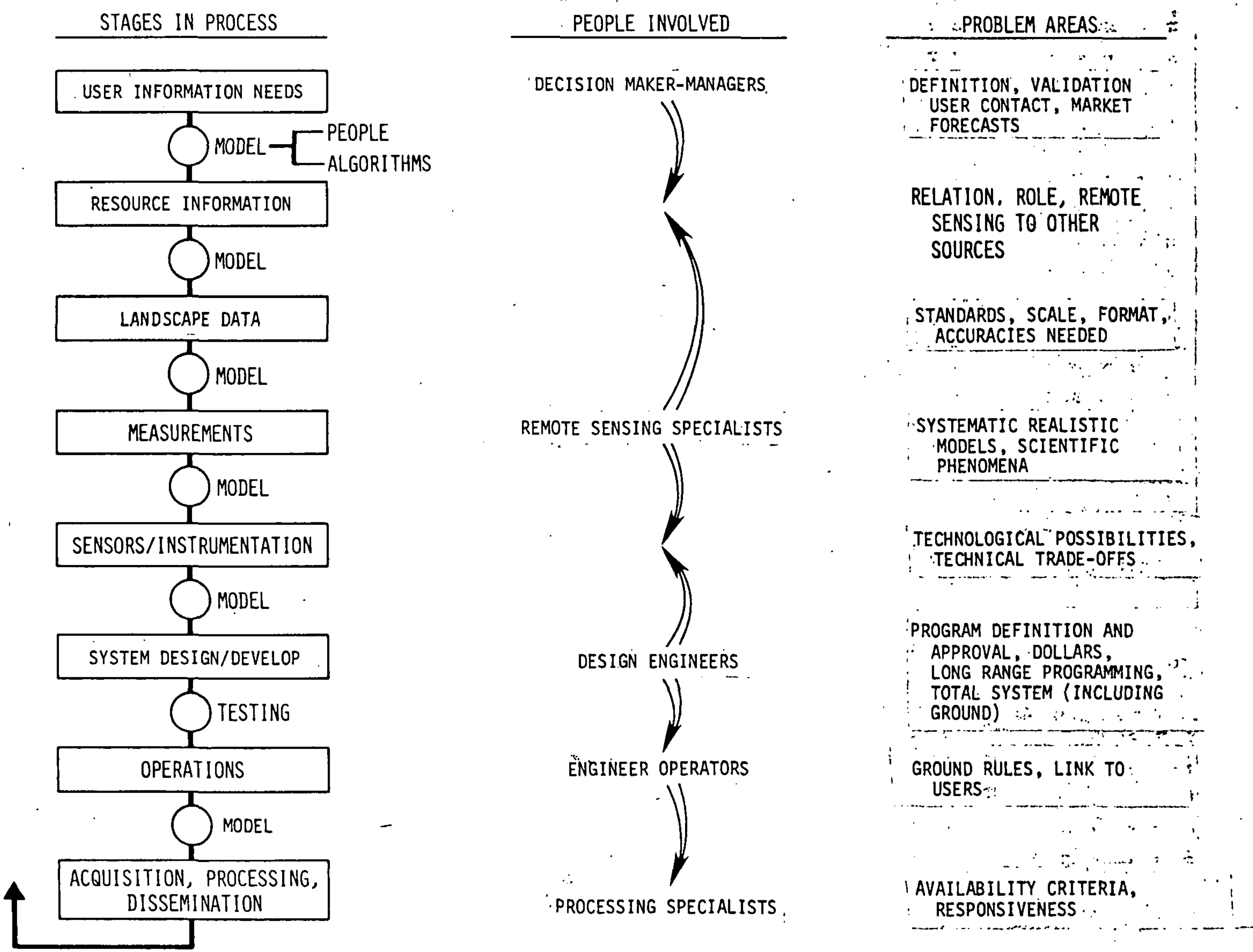
NASA, typically, "has not done well in defining the remote sensing data needs (scales, accuracies, formats, types, etc.) that allow measurment requirements (spatial, temporal and spectral resolution, etc.) to be defined. Data requirements are confused with measurements." NASA technology usually comes first, then users are sought.

Different people, skills and interests are involved at different levels of the user requirements process, and there are considerable differences in the way the stages in the process are visualized by those involved. It was found throughout the interviews and discussions that specific functions or activities related to individual stages in the process were regularly described, but very few observers outlined the full span--from user need to technical response--in a systematic way.

Figure 2 presents a consolidated diagram of the various stages involved in the generalized user requirements process, together with the types of

USER REQUIREMENTS PROCESS

FIGURE 2



people involved, and the problem areas most often cited for the stage. The reader is invited to review Figure 2 carefully, because it summarizes a considerable amount of data that are not further elaborated. (An example related to geologic mapping is presented in the Appendix). As noted previously, the technical content of each stage is different and many different methods (models) are used to effect the translation from one stage to the next. In practice, it was found that it was hard to pin down who was responsible for organization or management of the technical content of different stages. Except for narrowly focused scientific research, the span of the full user requirements process in most fields is too extensive to be managed totally from either end. The detailed content of the stages are, themselves, technically complex, and the models (people or algorithms) used to make the transformation from one stage to the next may also be complex.

It is important in the first instance for the senior people in all sectors to define the <u>problems</u> that are important. These need to be defined with sufficient authority and stability that they can be used as sound bases for the development and organization of requirements as inputs to the multi-year planning processes that accompany any significant space program.

As implied from the data in Figure 2, Tough and lengthy processes are then involved in organizing people to attack all levels of the requirements process. The complete process for most subjects is <u>very</u> extensive and complex.

The organization and management of requirements-related data that is developed in relation to these various stages is an old problem, and is reviewed in some detail in some of the older studies. . There have been many major ad hoc NASA and inter-agency Studies that have catalogued the various user problems that could be attacked via remote sensing. These have included data content of the different stages, the models involved in the processes of translating technically from originating statements of users' information needs, through the various stages, to the definition of remote sensing systems with characteristics responsive to those needs. There is, however, no currently consistent approach to the delineation of the different stages involved, even for planning and management support purposes. We found, in general, that most participants viewed the "user

requirements process" as involving no more than the contents of the stage-or-two adjacent to their own activities.

The few detailed studies that contain extensive assessments through the full sequence of requirements stages, are by now, from about four to ten or more years old. While they contain much data that remain valid, they also are enough out of date, to be questioned by critics, and to be doubtful as primary requirements bases for current programs. There appears, overall, to be little effort to deal with these steps explicitly in current programs.

2.2.2 Discipline Differences

The inherent difficulty in defining and managing the information flows involved in multi-staged user requirements processes is in some respects proportional to the breadth of the discipline and the scale and composition of the user community involved. There was general agreement among the observers interviewed, for example, that the full span of the user requirements process was the most easily managed for highly focused scientific investigations, and the most difficult for broadly based programs such as land remote sensing for Earth resources evaluation.

- Specialized scientific investigations are complicated in their own right, but most often involve small and select user communities, and concretely stated scientific objectives. Identification of the user information needs for an investigation may be spelled out in detail and their technical relationship to measurements and sensing instruments may be evaluated in highly concrete terms. The user-scientists may even be able to work closely with the sensor system design engineers to assist in design and provide guidance on technical trade-offs. The "stages" in the user requirements process are developed as needed, during the give-and-take evaluation that accompanies the search for the optimum technical approach to the investigation. The importance of the investigation and support for its conduct is generally sanctioned by scientific peer reviews and through scientific advisory bodies. In short, the "users" are largely scientists. The programs are research-oriented, aimed at

improving basic knowledge. "Requirements" are not separate aspects, but just part of the contunuing interaction that takes place on several levels. User needs are translated into a program response when circumstances are "ripe."

- Broadly-based programs such as land remote sensing, on the other hand, have so many overlapping areas of scientific investigation and practical application, together with extensive and heterogeneous user communities, that there is little possibility of having the close and direct interaction between "users" and remote sensing system designers that is feasible with a specialized scientific investigation. Different arrangements and mechanisms are needed to be effective in managing the development of more broadly based requirements. There are no established peer review mechanisms. A number of observers who were interviewed felt that one of the major problems in the user requirements area was that NASA's scientific orientation has caused it to develop user requirements generally by methods that are most nearly germane to highly focused scientific research. In the more broadly based program, "users" include personnel who need information for decision purposes. These programs are applications oriented. "Requirements" are definable at several levels, and to be responsive to user needs, there is a need to have accurate technical translation from level-to-level with some means of regular interaction between user interests and technical design interests. These do not exist today in any formal way.

2.3 USER COMMUNITIES

An effective user requirements definition process depends in part having a clear understanding of who the "users" are, and how they are organized collectively. "User communities" in the various applications disciplines differ widely in size, scope, location, and methods of interacting with NASA. The term, in the present context, signifies the collection of individuals and organizations that have a common interest or stake in, and use the products of, NASA-originated space remote sensing.

A key consideration in evaluating the NASA user requirements process is that NASA, itself, is rarely a member of the "user community". Its direct mission includes the development, construction, testing and operation for research purposes, of space systems. It has a more ambiguously defined role with respect to direct support of various user communities, although there has been general agreement that it should support at least the federal government agencies. The fact that NASA is rarely a "user" complicates the interaction process. Some of the observers interviewed thought that the main reason NASA doesn't have a comprehensive user requirements process is because it does not have functional (operational) responsibilities to acquire Earth and other sciences data for its own use.

A continuing issue in assessing the user requirements process, is how to identify the "user communities" that NASA programs serve, and the links that NASA managers should have with those users. Across the spectrum, the answer (again) is relatively much simpler for scientific investigations related to programs such as upper atmospheric research, than it is for broadly-based land remote sensing such as geology or agricultural crop monitoring.

The meteorological, oceanic and land-oriented "user communities" represent three groups having almost orders of magnitude differences in size and complexity.

- The civilian meteorological user community is described as very small, very specialized, and composed largely of Government(s) personnel. "There are about 6,000 professional people in this field in the U.S., and about the same number abroad. There is one principal U.S. professional society and one major international organization." Satellites have been in routine use for almost twenty years. Data products are distributed world-wide on a routine basis. Data users are largely professional meteorologists and there are customary channels for coordinating technical information needs. The roles of NOAA, DOD, and NASA are relatively well defined and under regular review.

- The civilian oceanic user community is described as much more diverse and difficult to coordinate than the meteorological. For

oceanic processes and services, there are perhaps tens of thousands of potential users vs. the thousands in meteorology. Oceanography is also far behind meteorology in development of numerical computational programs that record, analyze and distribute data. In many respects satellite remote sensing to support oceanic research and services is just beginning.

- The user community for <u>land data</u> represents an altogether different and larger dimension than meteorologic and oceanic. There are very large numbers of potential and actual users, and applications, for civil land remote sensing data. Tens of thousands of diverse civil users have worked largely with Landsat, to date, and are distributed worldwide throughout all sectors and many disciplines. Computerized geographically-based information systems are largely decentralized. Because the applications are so varied and the users so diffuse, the user requirements definition process for civil land remote sensing was characterized in one interview as a "tangled web of technology, users, federal, legal, and regulatory considerations."

An example of a small, closely-knit, user community was described as the field of upper atmospheric research. In that case, requirements were said to have emerged in the 1960's and gravitated to NASA when scientific concerns over ozone depletion developed. The concerns led to reviews of potential ways data could be acquired, with space-borne sensors turning out to be necessary. NASA then began to develop sensors, etc. The NASA research role became established, its scientific constituency became defined, and its congressional mandate was legislated. The "users" of most of the output of the upper atmosphere research, however, are a relatively small number of scientists who in turn, depend almost entirely upon NASA-sponsored and funded activity. These scientists are the user community in the narrow sense. The nation, or the policy makers who must make decisions on the basis of the scientific data, represent the user community in the broader sense.

An example of a more extensive and diffused user community is the geologic mapping and exploration community. In this case, "users" are distributed

throughout government, private, and academic groups, but only a relatively small number of professional geologists regularly use NASA remote sensing products (largely Landsat) for their experimental or operational applications. The potential future user community is much larger, but if it develops it will be an operationally-oriented, rather than research-oriented community. (See the Appendix for details).

As noted previously, there have been many elaborate functional classifications developed in studies that have related users, by type or organization, to NASA-originated remote sensing applications or possibilities. In detail, these identify literally hundreds of discrete subject fields--uses--spanning all sectors, and relate them to specific technological possibilities for scientific investigation or more routine operational applications. The studies that we reviewed ranged from the multi-volume cost benefit studies conducted in the early 1970's, Summer Studies and Symposiums in the middle 1970's, technical studies supporting systems designs, and studies such as the interagency Integrated Remote Sensing System Study (IRS^3) conducted in 1978-79. A variety of current study efforts within NASA and NOAA were also reviewed. From these as well as from the interviews, it is clear that specific uses of remote sensing technology have been catalogued in greater detail, and many times more completely than specific users.

A conclusion drawn from this review is that the number and complexity of the interrelationships between the uses and users, on the one hand, and space-borne remote sensing technology on the other, are so great that, to date, they have defied systematic management. Individual "users" can be identified as examples in most fields, but there is no agreed means of expanding that to a concrete understanding of (let alone, routine interaction with) the full "user community" in an aggregate or market context, except for narrowly-focused scientific research or experimentation. The inability to identify the user communities in some detail is a major weakness. As one of those interviewed put it: "You can avoid it for a time, but sooner or later you have to have a user community behind a program for it to be successful".

2.4 PROCESSES AND MECHANISMS FOR INTERACTION

Many types of processes and mechanisms for interaction were identified during the course of the present review. Both in the documents examined and in discussions with knowledgeable observers, the strengths and weaknesses of these tended to be cited rather uniformly. They generally were grouped according to their duration, in three categories: ad hoc; intermittent; and continuing. No single approach dominated others in terms of imputed over-all utility -- although there were questions concerning the effectiveness of many. Observations on the various processes and mechanisms for interaction are outlined below.

2.4.1 Ad Hoc

Much of the initial user requirements development in the NASA remote sensing applications area has been handled through ad hoc approaches. Ad hoc processes and mechanisms for interaction include specialized large Studies, Task Forces, one-time Surveys and Symposiums, and various types of Workshops. The following comments are based on data and observations encountered in our review:

- Large Studies were rather universally questioned in terms of whether they ended up being worth the effort. Several observers were emphatic in their views that large studies should only be undertaken when a major problem exists that has to be solved. Then attack that problem and present options and "what ifs." Provide only limited copies to the person(s) who has to solve the problem (make a decision). Studies should address action items. Studies for study sake: never. Too many Studies are just used to provide a stamp of approval on decisions already made. There are many exhaustive Studies that have box diagrams of all the user needs, their relation to data and sensors, etc. These Studies are not processes. They end up on shelves and in file drawers without follow-up. If Studies are interagency and OMB-involved, then there is excessive pulling and tugging by participants to control the results. These Studies do not get used either. Interagency Studies frequently have useful by-products in terms of people working together and having eyes opened, but it is rare to have

any follow-up. The resources marshaled, ad hoc, are dispersed when the Study is finished, and they are especially difficult to sustain and coordinate when the Study is lengthy.

- Task Forces are generally convened in the absence of having systematic processes for handling user requirements. Personnel are "borrowed" from their regular assignments. The output is generally a study, or documentation, to support the objective of the Task Force. USDA, for example, has used Department-wide Task Forces to address remote sensing requirements. The results included the "Secretary's Initiative" in 1978 that led to AgRISTARS. The Task Force catalogued thousands of individual information needs of USDA, and the remote sensing requirements related to them, in hierarchical order. It reached agreement on the seven top information requirements of USDA, in priority order and worked under senior management. After the Task Force, however, the people dispersed. While the process helped result in AgRISTARS with its interagency coordination and management mechanisms, it did not rationalize the processes within USDA. It did result in the constructive consolidation of information and requirements for the 4-5 agencies within USDA that were involved. There is often considerable reluctance to use the Task Force approach because of the drain on resources it involves and the uncertainties about effectiveness. Once disbanded, it takes a major cause to start it up again.

- One-time Surveys and Symposiums may be useful in collecting input data for user requirements analyses, or for information exchange, but it is generally quite difficult to organize and follow-through systematically on the generally large amounts of data involved. To be effective, considerable care must be taken in original organization, and in "quality control." Symposiums were criticized when it was judged that they were convened primarily for the purpose of ratifying decisions already made. Organization of data and reporting of results is generally time-consuming and frequently is too late to provide support for current decisions. Questionnaires were criticized on the grounds that they

generally resulted in "wish lists" and that it was very difficult to get questionnaires to the right people at the right time to be effective.

- <u>Summer Studies</u>. Several observers cited "Summer Studies" as among the most effective of the ad hoc processes, although they may differ considerably in focus and scale. One of the examples of effectiveness was described as the 1969-or-so study that developed requirements for NASA's geodetic satellite program. The key to the process was selection of a well regarded, independent geophysicist to head the study. He canvassed and selected participants. NASA arranged and facilitated. One week was on problem definition, and one week was on proposed approaches to solutions. The output of the study became an input to NASA in formulating a research program that was said to still carry through today.

  Another example, but with less clear effectiveness, was the 1974 Snowmass, Colorado, Summer Study, "Practical Applications of Space Systems," conducted at NASA request by the Space Applications Board, Assembly of Engineering, of the National Academy of Sciences. The Study's goal was to involve a representative group of users and potential users, organized in nine panels covering different application areas, in an intensive two-week study to define user needs that might be met by information or services derived from satellites. It made a number of recommendations dealing with user needs, with technology, and with institutional arrangements. One of its conclusions was that "institutional arrangements are inadequate for identifying the needs of potential users so as to provide direct and consistent guidance to technologists and the developers of space systems." Without evaluating it in detail, this type of study illustrates a mechanism for crystallizing widely-based information in a brief time, but also the problems of follow-up action on its findings, which were said to be limited.

- <u>Workshops</u> generally were judged to be of value when they involved small groups of experts who were convened to address relatively well and narrowly defined topics. They were criticized when perceived as "y'all come" exercises primarily to marshal support for predetermined conclusions. For user requirements development, the principal problems were sponsorship, selection of participants, and the administrative overhead that accompanies the organization, coordination, and reporting of the results. "It is common practice for NASA to sponsor workshops. Top management from participating organizations is invited, but generally they have to pick 2nd and 3rd level people to represent the agency. Participants have a good 3-4 day interaction, but not the key decision makers who get a second or third hand account."

<u>Conclusion:</u> The utility of <u>ad</u> <u>hoc</u> processes and mechanisms for interaction depends heavily on the clarity and focus of the objectives, the level of participation, the management competence and the soundness of the methods selected. When any of these conditions are absent, the ad hoc processes are ineffective. Ad hoc approaches are, by definition, difficult to sustain and are administratively complicated.

2.4.2 <u>Intermittent</u>

Intermittent mechanisms for user requirements development are those that are cyclical, or are repetitive parts of continuing broader programs. They include cooperative investigations, the basic budget and programming cycle, and periodic requests and reports.

- <u>Cooperative Investigations</u> that involve interaction and shared responsibilities between NASA technical programs and users provide a basis for development and refinement of user requirements. They have the advantage of being done in a setting that permits direct interaction between the "hands-on" user and NASA program personnel. They range from APT's (Applications Pilot Test) and ASVT's (Application System Verification and Transfer) in different sectors and subjects, to the wide range of Principal Investigators conducting joint research in a number of fields. These provide for periodic interaction between NASA and users for the

duration of the investigations, which frequently last several years. They are generally problem-specific, and cover relatively narrow topics, individually. As a group, at any one time, they consist of projects that are in vastly different stages of developmental analysis. These investigations, collectively, represent a rich source of requirements-related data, but are not uniformly directed to that objective. There was a common complaint concerning NASA's "Principal Investigtor" method of conducting research, on the grounds that the process generally offered too little visibility to outsiders, and the results were very slow to come out.

o The Budget and Programming Cycle obviously represents a regular and primary mechanism for review of user requirements as part of the program planning and justification process. NASA offices marshal and review user needs data during this process. A common complaint regarding requirements was that the budget process itself, drives NASA regularly toward technically glamorous and advanced projects at the expense of more prosaic projects that, nevertheless, were valuable to external users. Some users felt, for example, that views on user requirements were solicited by NASA only at budget time, and then only as part of a search for program justification data. "Users needs" were secondary. In this view, the user requirements process was not nearly as responsive to user needs, as it could be with a different focus. In the view of some, not surprisingly, it was felt that the OMB had become the senior user requirements entity in the government in the sense that user needs frequently were decided at that point. Most users felt they were totally isolated from those processes.

o Periodic Requests and Reports such as the RTOPS or 5- and 10-year planning documents provide a basis for updating and refining data on user requirements, but the RTOP is generally focused on relatively specific needs in relation to identified technology, and the long range planning documents present user data in highly summarized form. There was rather uniform questioning of the

practical effect that either series had on the development of user requirements, as such, and a belief that statements of user needs were inevitably tailored primarily to support the proposed technical programs. In that sense, the processes involve much more "technology push" than "user requirements pull."

Conclusion: The utility of the intermittent processes and mechanisms for interaction depends on having jointly defined interests, timeliness, and soundness of the data being developed. There needs to be a recognized user requirements development function and a greater opportunity for interaction involved for those approaches to be effective in the user requirements definition area.

2.4.3 Continuing

There are a variety of processes and mechanisms for interaction that operate on a continuing basis, but they are largely advisory. They include Advisory Committees (with their subordinate Subcommittee's, Working Groups, Panels, etc.); Interagency and multisector Boards; Academies, Foundations, and Councils; and Professional and Scientific Associations. Last, but not least in this category, are personal contacts.

- Advisory Committees and their subordinate elements were, on-the-whole, viewed with some skepticism, with questions raised as to whether they were, in fact, effective or useful. The problems most often cited were that people cannot open up with their real views, there generally are too many people involved, and the setting is too artificial. The participants are likely to "assert" requirements. (The higher the advisory group, the larger the egos.) Because they are "advisory", they do not come to grips with issues in the same way as the decision-makers who have to be responsible for the consequences of the actions they take. A frequent criticism was that members of Advisory Committees inherently had strong incentives to tell NASA managers what they wanted to hear. On the other hand, it was acknowledged that they represent a means of regular interaction with senior people who are external to NASA and, generally, the government. Continuity is often provided through supporting staff elements, but

these rarely have an independent role in development of user requirements data.

It was the general perception of those interviewed that NASA advisory bodies were too heavily weighted toward scientific/ academic personnel who were unable to represent effectively the interests of more operationally-oriented users. A larger role was encouraged for the latter, including provision for continuing interaction among federal government agencies. Although advisory bodies provide a source of continuing refinement of guidance on aspects of the user requirements they tend also to work primarily on agendas, and with information, developed by the NASA program/ project managers. The advisory group personnel are rarely available to provide sustained, independent inputs to the NASA planning process.

At the national level, there are many formal advisory bodies such as the National Advisory Committee on Oceans and Atmosphere (NACOA), the Water Resources Council, the National Research Council of the Academy of Sciences, etc. They have formal charters, prestigious memberships in their fields, and permanent staffs to support the discharge of their advisory functions. In the final analysis, however, these bodies were perceived to almost always lack clout. By definition, they are advisory, with distributed responsibilities and they cannot push through controversial actions. There are too many ways to block or veto. Statements of national level requirements by Advisory Committees provide <u>support</u> to programs, but they rarely <u>drive</u> programs.

o <u>Interagency Coordinating Boards and Committees</u> There are a variety of mechanisms to coordinate interagency or intersector requirements in conjunction with other activities. The Space Science Board of the Academy of Sciences was cited as an example of an effective mechanism for the scientific R&D community to identify and order its requirements. It involves high-level Panels that think far-sightedly regarding earth sciences and devise experiments. Key questions in advancing sciences are

framed through the Academy. Panels were said to have a generally good mix of people, with "authorities" identified by peers. It was said to be an appropriate group to support NASA regarding science needs. At the level of applied "operational" user needs, there are no equivalent mechanisms. The "Program Board" for land remote sensing, directed to be formed by PD-54, has not functioned to date, and was cited as an example of the problems encountered in establishing formal interagency machinery for coordination of policy and for information exchange. Bureaucratic interests, and difficulties even in defining and coordinating a charter are inevitable and, controlled in important respects by elements (such as OMB) that are external to the responsible agency (NOAA).

For years, there was a federal interagency coordinating mechanism for civil remote sensing, the ICCERSP (Interagency Coordinating Committee for Earth Remote Sensing Programs). It had a charter, minutes, etc., and was chaired by NASA with senior representatives from throughout the federal government. It examined civil applications satellite programs, had hundreds of meetings, developed numerous large papers, but "decisions were always made in small select groups." ICCERSP was allowed to die in conjunction with the Carter Administration Space Policy Reviews, conducted by the Policy Review Committee (Space), and no subsequent mechanism has replaced it at the senior SES level. The present "Cabinet Council" mechanism provides for interagency policy review of issues, and for coordination, but it appears to be largely ad hoc in its approach, and largely controlled by central (Executive Office) staff elements.

- Scientific and Professional Associations provide means for the extensive interchange of a vast range of information, including exchanges of data on user needs. There have been various proposals to establish relatively formal mechanisms, under the aegis of professional/technical associations, to define and order requirements in these fields. The idea was to capture the professional knowledge and expertise embodied in the association and

use it to assist NASA in coordinating and defining requirements. Such proposals have never developed to fruition. NASA regularly supports conventions, symposiums, etc. conducted by Associations in relevant fields. Virtually all of the persons interviewed regarded these as necessary and valuable sources of information, technical stimulation, and professional contact. At the same time, there was criticism of the in-bred outlook frequently involved, the large numbers of associations, and the level of demands on NASA personnel, as well as the lengthy interval between preparation of research work and its publication. There was also the repeated statement that "operationally significant findings" are almost never published in professional journals, with the result that it is very difficult to audit progress in operational applications, except by inference or through personal contact.

- <u>Personal Contacts</u> were almost universally regarded as one of the most important mechanisms in the process of developing user requirements data. Some relatively senior people thought that personal contacts <u>were</u> the user requirements process, in the sense that a combination of formal and informal contacts was regarded as the only effective method with sufficient flexibility and breadth to develop a good insight into the range of interests from user needs on the one hand to technical responses on the other. In this view, the project or program manager would make requirements related decisions largely on the basis of inputs from the network of personal contacts in the field involved. The most commonly cited criticism of this process was that requirements too often were formulated by an "old boy" network or a "cozy club" of self-interested people that excluded the interests of many users. Interested parties external to the in-group were largely in the dark and had no means of interaction. Critics argued for more orderly and more broadly-based processes. It seemed evident, particularly in the review of the geologic mapping and domestic crop production user requirements processes, that the participants in these processes relied heavily on the informal network of personal contacts among the relatively small

numbers of professionals who were performing the leading edge research on applications.

Conclusion: The utility of the continuing mechanisms and processes for interaction and the validity of the data developed through these means depends upon representative participation, defined roles for the participants, and the presence of incentives to identify and sharpen user requirements as an ongoing part of the total planning and programming process.

Overall, it is clear that there are many more types of processes and mechanisms available than are germane to individual disciplines or problems. There was little or no consistency in the evaluation of the potential utility of the different approaches, except the common view that some (undefined) small number of mechanisms should be employed together in evolving improved user requirements processes, and that the key ingredient for effectiveness is that they play well together. The implication of this is that mechanisms need to be chosen carefully with an eye both to their immediate function and to their compatibility and relationship to other mechanisms involved with other stages of the total process.

2.5 STRENGTHS AND WEAKNESSES

A number of strengths and weaknesses in the current user requirements processes surfaced consistently in the course of our review, both from analysis and during the interviews that were conducted. The most frequently cited are summarized briefly in the following paragraphs. Any evolving user requirements process should attempt to preserve and enlarge on the strengths as well as alleviate weaknesses. The strengths and weaknesses, in many respects, reflect perceptions of the overall thrust of NASA activity broadly, including the remote sensing area, rather than being uniquely related to the user requirements process. They have a significant bearing, however, on the handling of user requirements.

2.5.1 Strengths

There were six characteristics that were most frequently cited as strengths in NASA's approach to the user requirements process.

- Technical Talent. There was a uniform view that NASA's greatest strength was in its "superb collection of technical talent." This talent had been marshaled, of course, for many purposes beyond the user requirements process, but it provided at the same time a ready access to data and a rich reservoir of expertise when evaluating technical aspects of the user requirements. Preserving this pool of talent as a national resource and keeping it challenged, was cited as a major problem.

- "Can Do" Innovative Approaches. The mission and activities of NASA in the past has engendered a tradition of "can do" innovative approaches to problems. External users found this especially valuable in their efforts to find technical solutions to some of their problems, and to relate new technology to their information needs.

- Structured Review Processes. Because of its scientific and engineering focus, as well as the innovative nature and magnitude of some of its programs, an internal review process has evolved that includes elements outside of the direct management chain, including advisory bodies external to NASA. The strength of this is that it broadens visibility and marshals significant expertise and external opinion in the "normal" course of program or project review. This was sometimes cited as a weakness on the grounds that the processes unduly diluted management responsibility. When the process focused on substance (vs. form), however, it was viewed by external agencies as a significant NASA strength.

- Response to Concretely Focused Requirements. NASA's organization, processes, and overall management approach were characterized as geared-to, and strongest for highly concrete activities like Apollo ("land a man on the moon, and return him safely"), the planetary probes, and other scientific programs with concretely-

defined objectives. In these programs the "requirements" were established in the earliest stages and the focus and organization of subsequent activity became directed primarily toward execution. This includes a variety of R&D requirements.

- o <u>Professional Contacts</u>. The NASA scientific and technical specialists engaged in remote sensing programs across the various disciplines were characterized as very good at maintaining informal professional contact with colleagues in other organizations and sectors. The openness of the NASA activities allows for easy access and information exchange, and the tradition of professional interaction through Associations and publication of findings resulted in the existence of informal networks of contacts that the participants relied on for primary information exchange. NASA also has had a policy that encouraged NASA support to the activities of the professional Associations.

- o <u>Responsiveness to External Requests</u>. As a generalization, NASA was characterized as being unusually responsive to external requests or initiatives for supporting research or experimentation in remote sensing. In part, this was said to be a reflection of NASA's search for constituents, or "for technology in search of a mission." Regardless of imputed motivation, observers consistently cited as a NASA strength, the willingness and responsiveness of its personnel to attempt to assist external organizations in meeting needs that they identified.

2.5.2 <u>Weaknesses</u>

There were seven examples of weaknesses in the user requirements processes that were cited most frequently. Some of these affected the overall ability to capitalize on the strengths, above.

- o <u>Channels for Interaction</u>. There are few established channels for interaction between users and the various technical specialists in NASA who are attempting to act on the information needs that they perceive these users to have. As a result, there is much unevenness in the way interaction is handled among components and

disciplines and uncertainty on the part of many users (and NASA personnel) as to the channels to use. Trial and error is the frequent inefficient outcome. The absence of established channels is a disincentive to interaction because of the time and energy sometimes involved just in "getting through to the right place."

- Planning Information. There is little routine exchange of timely planning information between users and NASA, especially in the broader programs such as land remote sensing. There are few mechanisms for such an exchange. As a result, users frequently learn of changes in NASA planning too late to be effective in communicating the user requirements implications, and users also at times incorporate NASA-generated data in their planned applications in ways that are inconsistent with longer range NASA planning. Lack of access to accurate, timely, planning data was cited frequently as a major stumbling block to effective external planning and interaction. Decisions on budgets dominated the other aspects of the planning processes.

- Ambiguous Roles. An almost universally cited problem by the external (and many internal) observers interviewed was that NASA turns out to be difficult to work with on user requirements matters because of ambiguous roles, authorities and responsibilities among its components. It was difficult to know where to go or to know who was in charge. The Field Centers like JSC, ARC, GSFC were perceived to have sometimes overlapping responsibilities and various areas of technical specialization, while HQs was still different. They appeared to outsiders like separate kingdoms. As a result, users frequently felt they were unable to interact effectively. There was a perception that the NASA organizational form to some extent deliberately limited clear lines of management responsibility ("creative competition"), but it is especially difficult for user communities to know where to communicate when management is diffuse. A similar ambiguity existed over R&D vs. "operational" roles for NASA activity, and over the

interagency roles of NASA and NOAA particularly in the field of land remote sensing.

- o <u>Stages in User Requirements Processes</u>. There are inconsistent approaches to the different stages of the user requirements process, and no accepted definitions, with the result that it is difficult to make cross-program comparisons, to aggregate the user requirements from different programs or disciplines, or to evaluate routinely the relationship of technology developed against one set of user needs in satisfying requirements in another.

- o <u>Ad Hoc Studies</u>. A regularly cited weakness of the current processes was said to be the heavy reliance on ad hoc studies that absorb large resources and cannot be sustained. These studies were also critized on the ground that there was rarely extensive circulation of results or any follow-up. As a result, even when effective data and conclusions were generated initially, their credibility and perceived relevance decayed rapidly with changing circumstances, and participating organizations became faced with the prospect of having to generate still another ad hoc study.

- o <u>Inconsistent National Policy</u>. One of the most frequently cited problems with the user requirements processes was that inconsistent national policy and goals impeded effective planning and user commitments. There was broad recognition and agreement that national policy involves complex issues, and that economic constraints may at times impede programs that are otherwise worthwhile. It was simply stated as a fact, that inconsistent policies or follow-through at the national level have seriously impeded the development of effective user-NASA interaction at the program or discipline level. Without a stable policy setting, it was argued that users were unable to organize or channel their needs or resources effectively.

- o <u>Differences in Perspective</u>. There were a variety of problems frequently cited in the interviews, that reflected differences in

perspective by users and NASA personnel. We were struck regularly by the absence of direct knowledge of each others' views, motivations and programs, that led to the perceptions. Collectively, the fact of these differences represented a major weakness in the user requirements process that should be overcome. Examples that were frequently cited were the following: From users: "NASA doesn't listen, it's programs are technology driven"; From NASA: "users don't know their own needs"; From users: "NASA planning is driven by the budget process -- bigger is better"; From both: "User planning is driven by the status quo -- better safe than sorry"; From users: "NASA buys its own constituencies." Almost all of those interviewed were familiar with these views and felt that these statements were accurate as reflections of how NASA and users viewed each other. On review, we found statements like these frequently to contain kernels of truth, but they also appeared to be inaccurate or unfair in a number of specific instances. They reflected overall the difficulties of maintaining accurate perceptions in the absence of established methods for routine communication and interaction.

3.0 EVALUATION

3.0 EVALUATION

3.1 ALTERNATIVE MECHANISMS

There are many alternative mechanisms that are candidates for consideration as elements around which the user requirements processes should be organized. The focus of our evaluation has been on attempting to identify alternatives that sustain strengths, alleviate weaknesses, maximize application to multiple problems, and simplify management cognizance.

Many of those interviewed had their own, sometimes strong, views on the elements that should be embodied in an effective user requirements process. Many of these were common. Collectively, however, they represented a relatively broad range of opinion and differing points of emphasis. Some of the alternatives are outlined below, with the "flavor" of the proponents views preserved in some cases. An evaluation is made of each alternative.

3.1.1 Use of "Integrators"

A number of persons thought that "integrators" were the key to having an effective process. In this view, there is a continuing problem for the various organizations involved (NASA and users) to maintain contact with "user requirements" in an authoritative way. User requirements, in turn, are crucial. Without them being established soundly, and authoritatively, programs sooner or later get into trouble.

Definitions and a recognition of the steps involved are important. The "user requirements process" must start at the top with user-oriented objectives; then, it must define system requirements that meet those objectives; and the third step is to demonstrate that the requirements achieve the objectives.

Development of an effective interface between users and satellite system developers is a very tough problem. The users themselves cannot bridge the technology gap. On the other hand, the simple aggregation of all users needs represents an unrealistic statement of requirements. The technology and the needs must come together in relation to what is really possible. The objective of the user requirements process must be to provide a sound, realistic basis for establishing the characteristics that are, or will be,

embodied in a satellite system design, including ground processing and dissemination criteria.

The approach to such requirements is not very disciplined today. For one thing, users do not know what they need to, or can, have from satellite remote sensing, in terms of how to make better forecasts or make better decisions. It can be avoided for a time, but sooner or later, a user community must be behind a program for it to be successful. To date, defining the objectives for many programs has been a "lot of arm waving." The Landsat program, for example, was commonly perceived as having done little in defining what needs to be done.

"The trick in the business is to find those specially gifted people who are able to bridge the gap between the users and technologists: Integrators, who look both ways." The Landsat community, again, is described as very large, with probably 20,000+ direct users, some 1,000+ professional papers, alone, per year, etc. The necessary ingredient in developing an effective user requirements process, under these circumstances, is to find those key people who can operate across the span of these communities. They are few in number, but they exist, and can be identified. Then the task is to organize them.

A systematic Working Group of integrators ("key" users) should be formed that is then made intimately involved in the decision making process. This general approach should be used in all programs. The Working Group should be established formally to assure continuity and effectiveness, and it would need to have some full-time staff support to capitalize on the expertise of its members.

EVALUATION: Accurate perception of problems; strong in consolidating expert opinion; weak to challenge of "old boy" net; organizational placement and management uncertain.

3.1.2 Senior Coordinating Committee

In this view, one of the most important needs is to have an identified federal government vehicle for regular communication. The need is for senior people to be talking to each other on a regular basis, with the

members pegged at the top level of the Senior Executive Service (SES), perhaps edging into some political appointees. The level would be similar to the former ICCERSP. Such a committee would need to be able to carry weight with OMB and Congressional Staffs. There probably should be two kinds: one involving the scientific community, looking at "blue skies" aspects of key interest to NASA in terms of R&D. The second would be for "operational" users, looking at the interests that they have in NASA activities in many fields.

It is important to be realistic about what can be accomplished through a federal broadly-based interagency coordinating group.

- As a minimum such a group would provide a mechanism for regular, routine, exchange of information and a channel through which a variety of interests could be communicated.

- To be effective, any interagency mechanism should have top-level backing from the participating organizations, and have some full time staff support to be able to provide useful service to these organizations.

- It would be more effective for NASA if an external organization chaired such groups. An external scientist, for the scientific group, and someone with a user-orientation for the other. The "Program Board" directed by PD-54 has some elements of the latter (operational) type committee, but it has not functioned effectively to date.

- Representation is a difficult problem to deal with..."who speaks for a Department...?" Each major Department or Agency is independent and often has a number of Bureaus, Services, Agencies, etc. that are themselves largely independent with differing interests and relationships. Remote sensing interests are often difficult to identify and aggregate because the output of civil remote sensing systems are invariably complementary to conventional sources of data for most user programs including even scientific.

EVALUATION: Fills a current gap; strong in forming the basis for routine communications; weak in clout ("committee") and absence of non-federal interests; will take time to be effective.

3.1.3 Mission Definition Office

In this view, it is very important to define "user requirements." Their main role should be to support definition of space systems that are responsive to user information needs. It is important to decide at the outset whether the objective is scientific research, experimental, operational, or some combination. It is also important to decide who is responsible for what.

- The wrong approach is to design the system first, and then look for uses, "but that has been the practice". In such cases, the requirements process is poorly carried out because the structure is already constrained. People are trying to get answers (requirements) on what they are prepared to do already.

- NASA should have a requirements process rather than a series of one-time events. The "big bang" approach to requirements doesn't work. The reasons for the absence of a process are complex, but apparently stem from the larger processes of developing satellites, with spasmodic needs for data, and short deadlines. The tendency is to use a "wise man" process. It's a practical approach at the time, but falls short in the crunch. The requirements are not believed externally.

- A major weakness is that responsibility is diffused in NASA. It would be useful to have a Mission Definition Office responsible for ongoing consolidation and exchange of data on user needs and technological possibilities. The lack of clear cut responsibilities or stable requirements today, is a major demotivator for almost everyone involved.

- There is a need for persons defining requirements who have the broad view of user needs and applications. (Similar to "integrators"). Users are generally not prepared, or competent, to

answer technically-oriented questions about their needs. "There should be a process with translators who can relate the information needs of the users to the measurements that can be made via remote sensing. Then, iterate with the builders of the space systems. The builders can define the limits. But it must be a continuous, reiterative process."

A number of observers were struck by the extent of ambivalence within NASA on where to lodge responsibility. "Creative competition, has its place, but within limits."

In this view, the ambivalence on responsibility and objectives today leads to justifying systems in every possible way: R&D and operational. At the same time, "nothing is more destructive in system and program design than uncertainty and repeated changes in the requirements. There are many examples. Guidance today is fragmented and largely undocumented. A Mission Definition Office, properly functioning, would provide stability and continuity."

- The user requirements responsibility should not be placed in the Field Centers, "because they would simply undercut each other." Therefore, this responsibility should be lodged in NASA HQ, somewhere. ("Even when there is good work at one of the Centers it is common for it to be distrusted by the other centers and by HQ.") In any case, the user requirements definition function should be in a separate office that can be "objective."

- The approach would be to develop a specialized "requirements" focus through teams that would take on the tasks of developing data for long range planning (vertical), and interacting with user communities (horizontal). It should attempt to have a "market" outlook. It would be important to have a non-hostile, non-accusatory (lots lately) environment. The Office role would be not to fix blame, but to solve problems. It would be used as a creative, independent arm providing requirements-related guidance. Rotating tours could be used for staffing. It would need a careful charter dealing with how it responds and to whom. A key element, of course, would be the personalities involved. Field

Centers would end up as assigned lead centers on various programs.

EVALUATION: Focuses organizational responsibility; strong in consolidating requirements and technical data, and independent guidance "objective"; weak in the large number and complexity of user interfaces and potential to usurp line functions; could quickly improve and rationalize present data.

3.1.4 Clarify National Level Policy and Interagency Roles

This view was expressed by a number of those interviewed. It represents some of the perceptions of those who do not make policy, but are affected by it in their day-to-day management. In this view, the key to effective user requirements processes lies in the policy arena. The problem today is that there is no comparable commitment in space to man-on-the-moon. Apollo was a ten year program with national support: public, executive, congressional. Continuity was guaranteed once underway. Today, programs are year-to-year and do not have the psychological motivation of the earlier programs. There are no broad national space objectives within which programs can be executed. National "policy" has words, but actions deny them. PD-54 is "inoperative".

Who is the "user"? At the highest level, the nation is the user. At that level, space activities should still be approached broadly. The national objective should be to compete internationally and contribute to productivity domestically.

When it comes down to it, the key to the user requirements process is almost always the big "P", Politics and constituencies.

The political environment is key. Without political, highest-level, support, programs cannot function. It is more than planning, although good planning is essential to getting political support. The national decisions must be made first, with agreement on the policy approach. For example, balance of payments, international food/crop balances, energy resources, fishing, etc. Options must be considered and decisions made that will stick.

- In this context, the NASA user requirements process should focus on the following: "How can NASA take advantage of the needs of external agencies, and orchestrate programs that are responsive to those needs and draw support from the constituencies that these agencies have?"

- The impetus has to come from or be integrally supported by, other agencies dealing with agriculture, minerals, oceans, etc.

- How to make the best use of agencies and people in the context of public and private sectors, and politics, is the question. Unless these aspects are rationalized, the user requirements processes, and the programs they support, cannot be effective.

When considering the user requirements process below the national level, in the interagency context, it should not be NASA's responsibility to find out user's needs. Rather, it should be user agencies responsibility to communicate their needs to NASA.

- The user agencies have constituencies that they serve, and legislated functions. NASA's constituency should be the user agencies.

- The federal agencies with their missions, interface with the "ultimate" users. These agencies are therefore, in the best position to know what's needed. NASA should capitalize on these relationships. The user communities are too broad and diverse for an effective one-on-one NASA-user interface. There is a need for filtering and ordering, with clearly defined responsibilites.

- The delegation of user requirements development to external agencies creates problems, too, because intermediate agencies are not always attuned, which places NASA in the position of potentially having to work through organizations that have not developed good user interaction or that are not fully respected by the users. But there aren't good alternatives, because NASA cannot do it alone. NASA must focus on strengthening and supporting the other agencies.

It is important to recognize that there are ways to attack many problems other than by space remote sensing. "Remote sensing is like watching someone bleed to death...unless you know where to apply the tourniquet you won't get the right results..." The role of space remote sensing is two-fold:

- o To catalogue natural and man-made features, and to monitor changes that are taking place; and,
- o To identify anomolies that require more intense examination by remote sensing or other means.

To be responsive, NASA's role has to be focused on two somewhat different objectives:

- o Continued research, without direct regard for users.
- o Service needs identified by other agencies and users.

EVALUATION: Focuses on importance of national policy; strong in directing energy to first things first, and defining NASA's constituents (other agncies); weak in defining "how" to proceed and in elaborating instrumentalities; pragmatic.

3.1.5 Private Sector Market Approach

In this view, the requirements definition process must come back to the classic market framework. The ground rules should be that a "requirement" hasn't been defined until a user has been identified who is willing to pay for the eventual product. A major difficulty today is that the market place is artificial. The federal government picks up the tab. The "true" worth of space remote sensing products are therefore difficult to establish. The total market, in turn, includes not only government agencies but also the other sectors, and is both domestic and foreign. To be effective, the user requirements process needs to take account of the aggregate market.

A problem is that the Government cannot easily treat narrow interests. The Government is set up to meet broad needs. A Private firm can look as narrowly as it wants. In the aggregate, the latter results in servicing a much broader total market.

Industry has to define requirements very carefully because the governing element is the ability to pay. The Government is poorest at defining requirements because ability to pay doesn't come into play to the extent it does for commercial activities. The Government is also generally poor at marketing, because it has no incentive to develop a market in the context of selling and evolving products.

- A private owner needs to have end-to-end control to deliver specific products against contracts, or go out of business.

- The Government does not go out of business if it fails to deliver. In many instances it provides its products/services without charges.

In this view, NASA has a legislated mandate for research, but all such research, except some basic, should be connected with defined "operational" demand. In a first-order sense, NASA's biggest customers should be agencies like DMA, CIA, BLM, etc. If a corporation were the owner/operator of the civil land remote sensing system, for example, its life blood would be in determining user needs (requirements) and selling products to customers.

NASA is a poor marketeer, for many of the reasons cited above. "One of the problems is how to take the pulse of the user agencies in the federal sector that make up a sizeable part of potential demand. At present, USDA represents no one but USDA; USDI represents no one but USDI; etc. These agencies may have opposing interests in various NASA programs or proposals." In the past "the NASA mentality was to decide how to use technology, and proceed regardless of users' views. NASA program survival now dictates that it listen more closely."

While it will be very difficult for NASA to approach the user requirements process as though NASA were a private firm, it should, nevertheless, organize these processes in ways that take the private market-oriented outlook directly into account, including explicit recognition of the importance of "operational" users interests as the starting point, even for research activities. No single mechanism is likely to be optimum. It is important

to define objectives in terms of their value to users in a cost-oriented context.

EVALUATION: Is consistent with emerging national-level policy on private sector approaches; strong in identifying forcing functions; weak in defining modalities; difficult to separate "requirements" from broader issues of private sector ownership/operations.

3.1.6 Multi-Level Iteration

In this view, is is very important to handle requirements definition systematically, and the starting point on requirements definition should be at the aggregate national level. Start at the top, with the hierarchy of information needed to make decisions, and move to the supporting substructure needed to define two aspects:

- The problems that need to be attacked.
- The information required for these purposes.

If information can come from remote sensing, it then needs to be defined in terms of scales, accuracies, formats and types of data involved. Down to that level of specification it is not necessary to have remote sensing specialists.

It is first of all important to understand the objectives of the users. The point is that users needs do not necessarily match NASA engineers' views of these. There are a number of discrete stages in the process of moving from a statement of user needs to the ultimate translation of these into a form usable for technical system designs responsive to the needs.

For NASA to do its job, it must know fully the data/information processes of the major user fields. Then smart people can begin to bridge needs and technology. NASA typically has not done well in defining the remote sensing data needs (scales, accuracies, formats, types) that allow measurement requirements (spatial resolution, temporal resolution, spectral resolution, etc.) to be defined. Data requirements are confused with measurements.

It is _very_ important to understand the upper end of the requirements spectrum...the _national_ problem. Beginning at that level, the multi-level iteration approach would convene relevant people at the various levels, work out the requirements, and write a report at each stage that would be an input to the next stage. A senior NASA person would follow the process all the way through, producing the reports, circulating the critiques, etc. The overall sequence would take a long time to cycle, but there are no short-term fixes.

- o The first step would involve working the upper end of major national problems...energy, food, minerals, etc., with a few people, to identify the problems of highest potential return and importance. This would involve Assistant Secretary, Chief Scientist, VP's of exploration, level persons to identify and bound the problems. No remote sensing people.

- o The next step would be at the management planning level involving some remote sensing people. This step would decide data needs, and the subset of these that can be attacked via remote sensing.

- o The next step is to work with technically skilled people to define measurements data.

- o The final steps involve the range of considerations and specifications that accompany development and operation of a space system and processing and disseminating its acquired data.

- o Throughout, there would need to be a recognition of the complexity of this process.

For the first step, it would be useful to have one-on-one pre-discussions at the Associate Administrator level, then a letter outlining desired participation and objectives.

Throughout the process, one level of iteration should have an output that identifies and outines the interaction needed at the next level.

At all stages of a phased user requirements process, the approach should be to develop a strawman, representing the best thinking and documentation

available, <u>before</u> convening people to interact. <u>Never</u> group-grope on these issues. The function of the interaction should be to test the validate and modify the strawman. Then coordinate and evaluate. The overall objective would be to <u>evolve</u> a stable and authoritative body of user requirements documentation through the different stages, that would be available to a wide range of interested parties externally, and be useful for program review and justification internally.

A variation of the foregoing approach would be to provide for a continuing iteration through the various stages via permanently established user-oriented Panels, for the various disciplines, that would be responsible for reviewing the requirements periodically.

EVALUATION: Thorough and systematic; strong in detailed recognition and treatment of the multiple stages involved; weak in the complexity and administrative difficulty of sustaining the full process; would need substantial support and continuity of direction to be authoritative.

3.1.7 Continue Current Mechanisms

Throughout the present review it was found that the characterization of the user requirements process that was outlined by the NASA sponsoring organization at the beginning (p.1) was largely accurate. This was true, both in terms of the way in which the processes were <u>perceived</u> by those involved, and also the way they actually <u>operated</u>, based on analysis of the data developed in our review. In most instances, those who supported continuation of the current approach viewed it as the best that could be done under the complex combination of circumstances that NASA faced. The current mechanism, in their view, struck a practical balance among all of the conflicting forces involved.

The current mechanism lodges responsibility for the technical development of the user requirements at the Division level with individual program managers for various disciplines. In this view, the process works within a hierarchical framework. The NASA Administrator defines policy, programs, etc., <u>broadly</u>. The Associate Administrator (Office) then translates these into program guidance. Finally, the HQ Divisions activate the individual

programs in conjunction with the Field Centers where the principal technical expertise resides. In theory, HQ is the source of policy guidelines. Within this framework, the HQ program Directors have the nominal responsibility to identify and define the user requirements and associated measurements, and to be the principal NASA interface with "users." Project review with the centers takes place at NASA HQ, but "it does not generally represent an <u>exchange</u> of data on user needs, etc. The principal interacting mechanisms are at the Office level, not really at the program manager's level." Field center personnel interact with various "users" regularly in connection with specific investigations, but otherwise it is at their own initiative, not because they have assigned responsibilities to develop user requirements, as such. There are, of course, exceptions to this generalization.

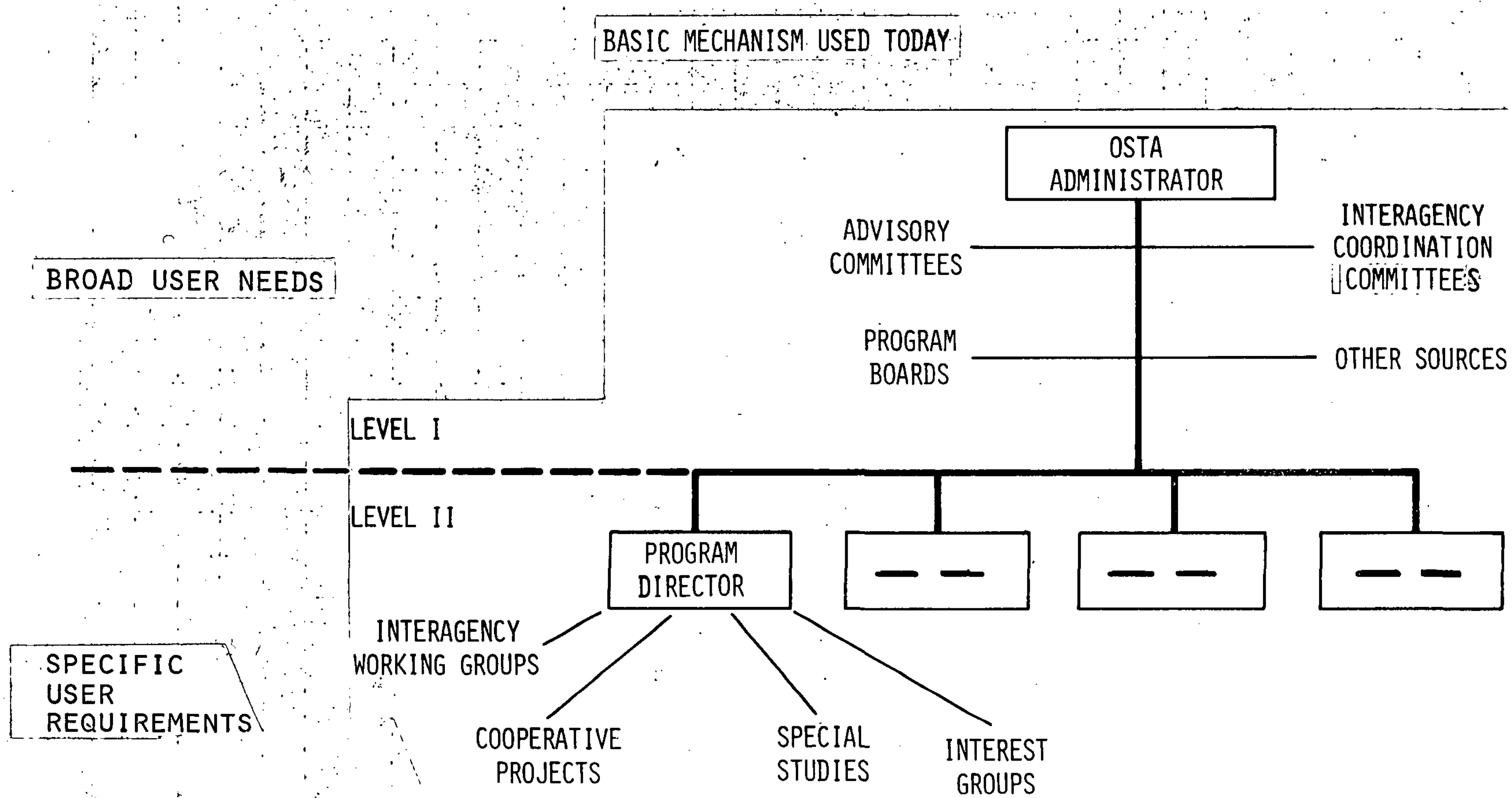
A simplified diagram of the basic mechanism used today is shown in Figure 3.

In this approach, there is no set way of defining the user requirements and acting on them. The processes are ad hoc and adjusted to circumstances. In each of the discipline areas, the NASA program directors maintain cognizance over user requirements in the relevant subjects, and translate these into the forms needed to support program responses when they seem appropriate. The "user requirements processes" are embedded in the program development and reviews that are part of the budget cycle. At the senior level, the Associate Administrator is the ultimate authority on the "user needs" and the research or other objectives that the programs should attack.

Individually, each Program Director has considerable latitude in choosing the approaches to be used for a program. The development of user requirements data, and user involvement, are also by methods and techniques largely of the Director's choosing. Each is tailored to the programs involved and the management philosophy and outlook of the Program Director. This approach allows the Program Director maximum flexibility in selecting and shaping the mechanisms to be employed, and it allows exercise of initiative. It may, or may not, fit well with the approaches selected by Program Directors in other fields.

USER REQUIREMENTS PROCESS

FIGURE 3



EVALUATION: Handles user requirements matters on an "as needed" basis; strong in management flexibility and exercise of initiative; weak in external credibility, in its singular dependence on key people, and in its utility in supporting cross program evaluations; a stand pat approach.

3.2 ELEMENTS OF AN OPTIMUM PROCESS

We have attempted, in this section, to identify the elements of an optimum user requirements process, and to define the conditions that are necessary for the processes to evolve from today's largely ad hoc practices into an increasingly coherent and responsive system. Even a cursory review of alternative mechanisms, singly or in combination as in the previous section, shows that there are many different approaches and points of emphasis. Clearly, no single mechanism is likely to be optimum for all important considerations. In an attempt to integrate the conclusions from the preceding sections we have summarized, in Figure 4, the elements that appear needed in an optimum user requirements process and the necessary conditions that should be established for the elements to function effectively. The needed elements are as follows:

- Continuing Process. Our analysis supports the conclusion of most of the managers interviewed, that the ad hoc character of the current process is a major weakness, and that a key to improved effectiveness lies in developing continuity in the processes so that user requirements data available to NASA and user managers is uniformly current and authoritative. The conditions that are necessary to accomplish this include the development of some form of permanent requirements evaluation structure that allows NASA and user personnel and interests to be focused jointly, with successive iterations representing improvements and refinements of preceding work. Experienced personnel should staff the processes to assure that the guidance generated is relevant, and that there are capabilities to cut through the inherent complexities of the subject matter.

- In-Place Mechanisms with Feedback. The absence of follow-up in the current processes--a major weakness--was most often attributed to the difficulty that both NASA and user personnel faced in

OAO CORPORATION

USER REQUIREMENTS PROCESS

FIGURE 4

CONCLUSION:

NEEDED	NECESSARY CONDITIONS
• CONTINUING PROCESS	• PERMANENT REQUIREMENTS EVALUATION STRUCTURE WITH EXPERIENCED STAFF
• IN-PLACE MECHANISMS WITH FEEDBACK	• DEFINED RESPONSIBILITIES AND DESIGNATED VERTICAL AND HORIZONTAL CHANNELS
• VISIBILITY	• TIMELY EXCHANGE AND COORDINATION OF PLANNING DATA
• REPRESENTATIVE PARTICIPATION	• ACCESSIBLE USER IDENTITY AND QUALIFICATIONS DATA; SELECTION CRITERIA
• STANDARDS FOR EVALUATION	• ACCEPTED GROUND RULES; DEFINED OBJECTIVE AND PRIORITIES
• COMPREHENSIVE	• RESEARCH, EXPERIMENTATION, DEMONSTRATION, AND OPERATIONAL ROLES CLARIFIED

determining who was responsible internally and externally for requirements-related matters, together with the difficulty of determining the current status of a previous action, study or initiative. A major, and sometimes fruitless, effort is frequently involved just to identify the responsible officers and the appropriate channels for communication. The necessary conditions for establishing in-place mechanisms that allow routine feedback, are to define unambiguously the responsibilities for user requirements development and interaction, and to designate the channels that are to be used vertically within NASA, and horizontally between NASA and the other agencies and sectors. Then, personnel at various stages in the process should learn how to work in the defined context.

- <u>Visibility</u>. The credibility of the user requirements basis for applications programs becomes subject to question when the technological parts of these programs proceed with little visibility on the part of users. External visibility and some exchange and coordination of planning data provides mutual assurance that there is at least the opportunity for interaction on matters related to the user requirements. Exchange is needed in both directions, so that the impact on user needs of proposed program changes can be assessed by the users, and the impact of changes in the user's needs can be assessed by the remote sensing manager.

- <u>Representative Participation</u>. One of the more difficult aspects of the user requirements process is in determining who the users are, and who should speak to requirements on their behalf. Personal contacts, self-initiated representation, and "peer group" selection are the most common current methods. Some user agencies have designated individuals on such matters. The most common complaint is that the process is an "old-boy" network. The necessary conditions for representative participation involve the development of comprehensive data on the user communities. This should include identification of individuals and groups of users, and their special qualifications or interests in the user requirements context. Selection criteria should be developed and

disseminated so that the requirements process becomes recognized as broadly based and representative of the full range of users.

- Standards for Evaluation. A current weakness is that the ad hoc methods used to develop user requirements data are so different from discipline-to-discipline and program-to-program, that comparisons and aggregations are difficult to generate, particularly for broader budgetary or executive reviews. Minimum standards for development and evaluation of requirements, together with accepted definitions, are needed. The necessary conditions involve the development of some accepted ground rules that would be used broadly in developing user requirements data to conform to minimal standards. These are complex to develop, but should incorporate views from both ends of the requirements spectrum. Objectives and priorities should be defined carefully to make effective use of finite resources.

- Comprehensive. The user requirements process today seems frequently to be operating at cross purposes in the sense that mission roles shift and are sometimes ambiguous. We found widely varying veiwpoints, for example, on the compatibility of "research" and "operational" user requirements and NASA's role with respect to these. It appears to some that these distinctions are artificial and largely semantic, and to others that they are real and should dominate. A weakness in the user requirements process has been the inconsistent NASA and user approach in this area. A necessary condition for the evolution of a comprehensive user requirements process is clarification of the NASA role with respect to research, experimentation, demonstration and operational user objectives.

In the course of our evaluation we found consistent identification of some or all of the elements above as needed in an effective user requirements process. There was also a consistent recognition that these elements are not equally present in many of the mechanisms that are available to be used. The evolution of improved user requirements processes entails management emphasis on these elements when the opportunities occur.

3.3 CONCLUSION AND ISSUES

The baseline characterization of the user requirements process, that was outlined by the NASA sponsoring organization at the beginning of our review, was found to be a generally accurate portrayal of the current processes and reflects the problems encountered. The current ad hoc processes tend to leave programs disconnected from users, and particularly vulnerable during the multi-year development cycle especially when challenged on the basis of user needs. Some of the weaknesses in the current processes can be overcome through employment of the elements identified with optimum processes, and those elements should be emphasized whenever possible.

It is apparent from the foregoing discussion that no single approach is likely to dominate all others in terms of effectiveness, and that the development of increasingly sound user requirements processes for NASA terrestrial remote sensing activities will be both evolutionary and involve balanced combinations of mechanisms that integrate NASA and user interests in a continuing process. NASA and user interests need to be combined in a more authoritative way.

There are, finally, several issues that go well beyond user requirements, as such, but have a fundamental impact on those processes.

- NASA Role. One of the most pervasive issues encountered in our review involved the question of the limits of NASA's role and responsibilities for different types of user requirements beyond narrowly defined scientific research. The widely ranging views and lack of consensus on this complex question are evident from the discussion in the preceding sections. Ambiguity, however, both internal and external to NASA, has a profoundly adverse affect on the development of sound user requirements data by senior and middle-level managers on both sides, because it introduces fundamental uncertainty concerning technical objectives, concerning who the "users" are, and concerning what interests of theirs should be served. There is no basis for a partnership.

Many observers felt that a narrow "research" interpretation of the 1958 Space Act by NASA failed to square realistically with the rapid evolution of technological possibilities that has occurred in the applications area. Transitional stages from research to demonstration to operation are more difficult to identify today. Ozone layer "research", for example, was deemed by some to be as "operational" as crop monitoring. External users, in particular, were uncertain about government agency roles (NASA-NOAA-DOD) and within the NASA context, were often confused by fine mission distinctions in either direction made by NASA personnel. Clarification of roles and responsibilities within NASA, and between NASA and other organizations, will facilitate, among other things, the development of more stable and effective user requirements processes.

- Information Management. The user requirements process represents a major problem in information management; that is, the organization and communication of data. Except perhaps for some basic scientific research, the number and complexity of stages involved in the total translation process, from initial identification of user information needs to the development of cost effective technical responses, are far too large to be managed efficiently from either end of the user requirements process. The total process necessarily, will be segmented, and some degree of specialization will be needed at different stages. Continuing attention should be given to the question of long range design and development of data systems that support vertical communication needs within NASA and horizontal needs in both directions between NASA and external users. The future capabilities and outlook for on-line computerized processing and dissemination of products of NASA remote sensing systems also has a range of embodied NASA-user issues.

- Priority. Tackling the user requirements process by itself is difficult because user requirements are only a part of the total planning process. In most fields, also, remote sensing data is only one of several potential sources, and there is dynamic

interaction among sources in a number of fields. We found, however, generally widespread frustration with the current user requirements processes, and little consensus on what to do about it. At the same time, we encountered the repeated admonition that unless the user-oriented basis of a program is established soundly, it will fail in the long run. These raise the issues of how to establish the priorities and set concrete goals in the technical programs that provide the basis for measuring success or failure in terms of satisfying user needs.

- National Policy. The absence of credible national policy concerning civil space programs in general is a major deterrent to the development of sound user requirements data. Some potential users doubt the utility of putting forth the effort to define their needs in relation to remote sensing. The policies that culminated in NSC/PD-54 are widely regarded as "inoperative". There is also widespread skepticism over the feasibility, at the present stage, of turning over the operation of civil land remote sensing satellite systems to the private sector under conditions that simultaneously meet the necessary private return-on-investment criteria, and the necessary government control criteria. Emerging foreign programs in some fields is further complicating the picture.

- Rationalized Approaches. In general, the differences of view concerning many aspects of NASA-user interaction, and the user requirements process, are so extensive that personnel at various stages frequently are ineffective because they are working at cross purposes, or because they are uncertain of their roles or objectives. It would benefit NASA and users to resolve or narrow these differences, at the very least in terms of government or NASA policy. To be effective, people must know who is responsible, know what the channels are, and be comfortable with the arrangements. The issue is how to balance the emphasis on different facets of the total process to accomplish those ends.

3.4 RECOMMENDATIONS

It is difficult to advance concrete recommendations with confidence, given the complexity of the topic and the independence and scope of this review. In particular, we cannot demonstrate whether our findings are the rule, or are exceptions to general practices. When relationships or views were found consistently, or were projected as generalizations by those interviewed or in documentation, we accepted them as probably the rule. We developed, of course, an extensive amount of detailed data that cannot be presented in a summary. Throughout, we attempted to evaluate data independently, as we found it, without initial regard for its bureaucratic or policy sensitivity.

We recommend that consideration be given to the following:

- Circulate all or parts of this Report as a basis for management discussion, and to determine how representative its findings are with the views of other NASA or user managers. In that process seek to develop a consensus as to key current issues concerning user requirements and identify priorities.

- Use the Report as background in further evaluating the strength and adequacy of NASA-user interactions and the status of user requirements for individual programs or areas of research.

- At face value, it appears that it would be advantageous for NASA to have an identified organizational point of focus for consolidation and oversight of the user requirements processes.

APPENDIX: GEOLOGICAL MAPPING AND DOMESTIC CROP REPORTING

APPENDIX: Geologic Mapping and Domestic Crop Reporting

We reviewed two subject areas, geologic mapping and domestic crop reporting, in greater depth than others to provide additional insights into the problems associated with the development and management of user requirements data for remote sensing in complex fields that have long established conventional practices and sources of data. In all, about 40 in-depth interviews were conducted with personnel in these fields, and we reviewed a wide range of related documentation. A detailed account of this material is beyond the scope of the present written Report. Some selected data and observations, however, are provided in the following sections.

Geologic Mapping

Geologic mapping is a continuing large scale activity conducted by government and industry to support decisions at many levels. These range from direct exploration for minerals or energy resources by private companies, to the management and leasing of federal and state lands by the government. Geologic maps present compositional, structural and chronological information needed to reconstruct the geologic evolution of a region or area of interest. The circumstances of the formation of rock units and their structural features influence, among other things, the occurrence of ore and petroleum deposits. In short, a geologic map depicts spatial arrangements of rocks at the surface and attempts to project the subsurface. It models a 3-D view of the Earth, stripped of vegetation, water, soil and culture, that depends on a combination of acquired data together with theories and concepts.

Geologic maps are the result of reiterative data collection processes that usually take a number of years to complete. In oversimplified terms, the conventional approach is to have appropriate education, and then with pick and hammer, compass, transportation (may include helicopter), and topographic maps or aerial photos for locational reference, perform on-the-ground survey at various levels of detail. In addition to field data, laboratory analyses are performed on field samples. Because of conventional training and long traditions of on-the-ground survey, the vast

majority of practicing geologists were estimated to place "remote sensing" low on their usual list of tools and techniques. These attitudes are changing, but slowly.

As a rule of thumb, it takes about 4 years, 20 man-years of effort, and about $2 million, for USGS to complete one 1:2,500,000 scale quadrangle (100 mi X 70 mi) reconnaissance geologic survey and its set of maps. These are just the beginning of detailed knowledge. Conventional geologists regard this relatively slow pace as simply a "fact of life" that is inherent in the field. Virtually all geologists believe it would be valuable to move at a faster pace. There is a current need for geologic data that will take many tens of years to acquire by conventional techniques. Remote sensing techniques offer the possibility of producing data from which geologic information about large areas can be derived much more rapidly than by conventional techniques. At the same time, only a relatively small number of geologists specialize in the direct use of remote sensing data as a principal element in geologic mapping.

The judgment of these specialists is that remote sensing can contribute significantly to the geologic mapping process in the areas of morphology, structure, and lithologic mapping. The groundwork has been laid with Landsat for the widespread use of synoptic image data for regional structural interpretation. Questions exist concerning the origin and importance of linear features (lineaments), their geologic age, their vertical extent, and their importance as conduits for magma and ore fluids. While much has been learned about the present state of the Earth's crust and mantle by geophysical methods, in particular seismology, the history of most of the past geologic events is finally recorded on the surface. Remote sensing is regarded as a powerful technique with which to unravel this history. Remote sensing techniques alone, however, cannot solve geologic problems. They must be used in combination with other data and techniques.

There still remain many possibilities in geologic remote sensing that will require new instruments and techniques with which to explore. Some of the future approaches include global stereoscopic imagery with spatial resolution many times better than Landsat; high spectral resolution imaging;

exploitation of mid-infrared bands, multifrequency and multipolarization radar systems; and active imaging systems in the near-and short-wavelength infrared region utilizing tunable laser systems to obtain data in very narrow spectral bands.

The principal geologic mapping in the U.S. is conducted by the USGS or by private firms. The focus of these activities, however, is quite different.

- o USGS emphasis generally is on geologically mapping all of a designated region or area, to provide a uniform standardized assessment of the underlying geology and general resources potential. The approach is very systematic and the USGS geologist is not really looking for anomolies, but only reporting them when found. USGS operates in a predominately mapping environment, and its efforts are directed almost exclusively at the 50 states.

- o Private mining and exploration firms, on the other hand, focus largely on detailed modeling of local geology within a region. They are looking for specific locations that are promising for drilling or exploitation. The private geologists are focused on finding resources, and their interests are frequently world-wide in scope.

A complex series of stages are involved in defining and translating user remote sensing requirements for geologic mapping. These are illustrated schematically in Figure 5, which also indicates the types of functional output associated with the stages, the people involved, and some of the problem areas. The very large dimensions of the information management problem that the full process represents are clear. It seems apparent also, that the full range is too complex to be managed effectively from either the user or the operational ends of the process.

To be effective, a requirements determing system must provide for people with geologic mapping expertise to engage in a process in which they interact with people who have expertise in remote sensing. Practicing geologists rarely have remote sensing expertise or computational expertise

USER REQUIREMENTS PROCESS

Figure 5

Problem: Geology--Exploration for Energy or Mineral Resources

FUNCTIONAL OUTPUT	STAGES IN PROCESS	PEOPLE INVOLVED	PROBLEM AREAS
Decisions: for on-the-ground exploration	USER INFORMATION NEEDS	Private Directors of exploration, Planners, Government policy officials for public lands, resources management, leases . . .	Data gaps many parts of world, and U.S....proprietary interests... uncertainty of future data sources... Priorities
	MODEL — PEOPLE / ALGORITHMS		
Geologic Maps: Geomorphology, stratigraphy, structure	RESOURCE INFORMATION	Corporate and USGS geophysicists, geologists Value added service firms	Choice of sources, data reduction, presentation...proprietary interests...geographic priorities
	MODEL		
Topography and surface cover: Rocks, soils, vegetation, water, culture	LANDSCAPE DATA	Corporate research analysts Value added specialists USGS cartographers	Standards for data characteristics to meet individual and multiple needs
	MODEL		
Specifications: Spectral bands, spatial resolution, area coverage, geometry. . .	MEASUREMENTS	Remote sensing specialists, investigators, scientists, academic research personnel	Systematic knowledge of relation between measurements and information
	MODEL		
Devices: Spectrometers mechanical scanners, RBVs, MLAs, films, microwave . . .	SENSORS/INSTRUMENTATION	NASA and Private Engineers, scientists, remote sensing specialists	Selection of cost-effective technology from among possibilities... long lead times...technology sharing
	MODEL		
Systems: OSTA-1, MSS, TM, MAPSAT, STEREOSAT, GRAVSAT, MAGSAT, LFC ...	SYSTEM DESIGN	NASA and Private Engineers, Field Centers, Space system specialists	Technical trade-offs. Selection cost-effective approaches, total system concepts...decision cycle
	TESTING		
LANDSATs, OSTA-1 . . .	OPERATIONS	NASA Field Center (GSFC) and HQ, NOAA, Engineers and computer specialists	Responsiveness, channels, continuity, reliability...operational ground rules
	MODEL		
Products: GSFC, EDC. . .	ACQUISITION, PROCESSING, DISSEMINATION	NASA/NOAA/EROS specialists user-geophysicist specialists	Continuity, responsiveness reliability of service...channels and feedback

of the type needed for computer supported digital analyses of multispectral data. NASA engineers, in turn, need to know what level of technological possibilities matters in relation to geologic mapping.

There is an extensive technical literature in the field that conveys the results of research and experimentation in the use of Landsat and other remote sensing products. An excellent summary article, for example, is "Geologic Remote Sensing," written by Alexander Goetz (JPL) and Lawrence Rowan (USGS), published in the February 1981 issue of the journal Science. This article describes the state of the art across the field, and includes some 60 references to other articles and sources. The main criticism that we found with professional publications was the complex and time consuming publication and review process.

A major problem with research findings is that they usually are onetime. Then, the researcher moves on to the next development of interest. The people who use the techniques and findings (private firms, etc.), don't advertise their results. It is very rare to see publication of successful operational uses of remote sensing in geology, although there are many, and continuing, word-of-mouth examples. Some believe that considerably more is being done by private companies than is generally known.

It is inherent in most geologist's professional training not to use remote sensing for geologic mapping because it is not seen as sufficiently understood to be repeatable. The conventional geologist is taught to rely on ground survey (truth). Geologists cannot yet demonstrate a one-for-one relationship between remotely sensed data and facts on the ground. Those geologists who have used Landsat have found that they can do many times more than they thought possible with the data. Spectral analyses, in particular, have yielded unique information. A major gap, however, is that the researchers still do not know what is really going on in the surface chemistry that causes the detected phenomena.

There is a relatively close, informal, professional, relationship among the small community of NASA-USGS-Industry-Academic personnel who are actively engaged in research involving the application of NASA originated

remote sensing data to geologic mapping needs. The high caliber of these personnel and their work was apparent.

One of the most difficult user requirements areas to deal with in the field of geologic mapping has been the private sector, partly because of the absence of formal relationships. In many respects, it seems that industry's interests are as fragmented and diverse as those of the federal Departments.

There were widely ranging views, for example, on the role and performance of the private Geosat Committee, formed in the middle 1970's. The original tenet was that there was a need for the private sector geologic community to have a mechanism to communicate to NASA views on geologic user needs and estimated value of information, similar to the relationship that USDA and USDI had to NASA in the federal sector. The extensive 1976 Workshop report on geologic user needs was cited by most observers as "still a pretty good statement." The principal criticism was that it attempted to define "requirements" largely in terms of resolution, spectral response, etc. in the context of technological possibilities perceived by the participants at the time, rather than in terms of data needs. Most of the participants were not remote sensing specialists.

We found a basic issue to be that of defining the current role that a mechanism like the Geosat Committee should have, and the type of interaction NASA should have with it. The views were varied, ranging from the suggestion that it develop strengthen "technical subcommittees" to the view that it should be pushing to make politicians more aware of the benefits and uses that are flowing to U.S. industry from the Landsat program and technology. The most common view was that it or something like it, was needed as an interface between government and industry. "It should listen to what NASA wants, listen to what industry wants, and help make the connection between technical possibilities and user needs." Some observers thought that, functioning as a non-profit group, it has been trying to take on the whole broad field of geologic needs, without sufficient staff or technical resources. A problem has been that companies participating in the Geosat Committee have such widely varying interests and perceptions of what is needed, that a consensus is difficult to achieve.

In general, there was a belief among the industry personnel we interviewed, that there should be more participation by industry scientists at the early end of NASA programs. The specific mechanisms were largely a matter of indifference, as was the question of whether there needed to be specific or implied powers in the industry-user's hands. As it was stated by one observer: "there is little interest in dictating how industry views are used, but considerable interest in assuring that NASA has a reliable means of knowing what those views are." Comments on the NASA-Geosat test site evaluation project were mixed. There was a common view that good technical results were being achieved, but that long and tedious processes were involved, including with computer processing of the simulated Thematic Mapper data. The project has proven complicated to manage and coordinate, in part, because of the complexities of government-industry interaction.

We found mixed views as to the significance of proprietary interests as impediments to the exchange of data, and in evaluating user requirements for various types of remotely sensed data. Industry personnel tended to downplay its significance. It has been a common practice to show NASA officials selected examples of results, at closed sessions, to assist NASA decision-making and program support.

We found a general belief that the distinction between NASA's "R&D" role and "operational" considerations is more a matter of semantics than a significant distinction. "It's a Washington problem. . .". While there are distinct "research" interests in many user areas, whether government or private, they were viewed as having the common goal of improving geologic mapping in the long run, and lacking significance if disconnected from "operational" applications.

New phenomena are being noted all the time that require practical and theoretical elaboration. For example, "it is being found that there is no such thing as an absolute seal, geologically. As a result there is vertical migration of hydrocarbons from subsurface entrapments. The seepage causes geochemical changes that affect botony and reflect differential compaction in the subsurface. These have significance to the exploration geologists." HCMM and future thermal remote sensing systems are "sleepers" in some geologists views.

Throughout the review of the user requirements processes for geologic mapping we found <u>many</u> examples of concrete applications and innovative work in process. We also found the mechanisms for interaction to be largely ad hoc and frequently informal.

As a generalization, it appears that in geologic mapping (as in other fields), the development of <u>technical</u> data expressing the technical relationships between specific remote sensing techniques and information useful to geologic mapping is far more advanced that the related organization of <u>users</u> and their collective understanding of the potential benefits remote sensing techniques may offer. The problem in part, is that there has been little of no development of user requirements in a market-oriented or similar context that allows parallel evaluation of the economic relationships or benefits of operational systems. NASA's role has been limited to technical research and a somewhat ambiguous interaction with other agencies and the private sector.

<u>Domestic Crop Production Reporting</u>

The relationships of NASA-originated remote sensing programs to USDA's domestic crop production reporting responsibilities are similar in some respects to those described for geologic mapping, but there are also important differences.

- Domestic crop production reporting is based largely on conventional on-the-ground surveying techniques that are extensive and long-standing, extremely rigorous, and thoroughly documented. In that sense, they are not unlike USGS practices in producing various geologic maps by conventional techniques.

- In the agriculture case, probability survey data are gathered every year country-wide by state and regional components, and these data are combined and expanded statistically into highly accurate estimates of <u>aggregate</u> national production for major crops. Experimental application of NASA remote sensing, primarily Landsat, has been aimed at reducing the margin of error in the national estimates somewhat and improving by a greater

degree the accuracy of estimates at the state or lower levels. Remote sensing products are "calibrated" by ground truth data collected for the probability survey, and then evaluated statistically by the application of very powerful computers.

- o In geologic mapping in contrast, remote sensing is aimed at independently improving the efficiency of on-the-ground geologic phenomena not readily detectable on the ground.

- o A major difference is also that the USDA is responsible for reporting repetitively and maintaining crop-to-crop series, both foreign and domestic, while USGS programs are more selective, longer, and largely domestic.

Domestic crop production reporting by the USDA is based on conventional on-the ground survey in conjunction with sophisticated statistical analyses that are highly standardized and computerized. It is necessary to understand these conventional techniques to appreciate the role and future utility of NASA originated remote sensing. It is obvious, on review, that the applications of NASA remote sensing to crop production reporting on foreign areas involve different sets of conditions and constraints, particularly in the use of ground truth to "train" computer analyses of remotely sensed products. The following paragraphs describe the domestic reporting program, in brief.

An orderly agricultural production and marketing system depends on an accurate and current accounting of potential output, available stocks, and the other factors that influence agriculture. USDA Domestic Crop Production Reporting is, therefore, a basic continuing large scale activity that supports decision-making at many levels, ranging from private sector marketing and distribution of products in the U.S. and abroad, to a variety of federal, state and local legislated functions. Crop reporting is the epitome of a federal "old line" agency program that uses sophisticated advanced techniques in discharging its responsibilities.

The Statistical Reporting Service (SRS) of the Department annually publishes hundreds of official reports detailing production and economic prospects for crops, livestock, dairy and poultry. Geared toward producers (farmers), this information is intended to help producers plan

their planting, feeding, breeding and marketing programs. The data also are used by agricultural services and businesses, trade groups and financial organizations to determine needed inputs, resources, transportation, and storage related to crop and livestock products.

Agriculture is the nation's biggest industry, and the nation's largest employer, with 14 to 17 million people working in some phase. Farming, itself, uses about 3.6 million workers, and 8 to 10 million people are involved in storing, transporting, processing, and merchandising the output. In all, about one out of every five jobs in private enterprise is related to agriculture. Because of its size and diversity, American agriculture is continually counted, measured, weighed, and priced to make it operate effectively and efficiently. There is close continuing cooperation and coordination of efforts between USDA offices and counterpart organizations at the state levels.

The unique qualities of the estimates issued by the SRS are their objectivity, comprehensiveness and reputation for accuracy. The methods employed in developing the official reports are all geared to maintaining the integrity of the estimates, because decisions involving literally billions of dollars a year are made by farmers, businessmen, and Government officials on the basis of agricultural estimates.

The overriding need for integrity, reliability, and impartiality in agricultural estimates is reflected in the laws, regulations, and procedures that govern the work of the Statistical Reporting Service.

Five titles and 17 separate sections of the United States Code are specifically addressed to issuing crop and livestock estimates. They govern most of the major operations of SRS, such as the security procedures and the exact timing for release of major reports. For example, the law requiring the Department to issue a monthly Crop Report says:

> "The data for the monthly Crop Report must be collected from practical farms in so far as possible. It must be printed and distributed before the 12th of each month. It must embrace statements on the conditions of crops by states and for the United States. It must

contain such explanations and comparisons as may be useful. It must be officially approved by the Secretary of Agriculture before issuance."

The widely known Crop Reporting Board symbolizes the care taken by SRS to protect the integrity of its estimates.

While Crop Reports are being prepared, the Board rooms are locked and placed under uniformed guards who also patrol the area outside the lockup quarters. The SRS computer system is also secured against tampering. There is no communication out of the area.

After the report is assembled, it is signed by all members of the Crop Reporting Board. The report is then reviewed and signed by the Secreatary of Agriculture (or Acting Secretary). However, no one has access to the survey data for the major producing States before the lockup begins and the Secretary or his representative does not see the report until he enters the lockup area to sign the report just prior to release.

The Board releases its reports to the public and news media at the times specified by law.

Crop Reporting

Domestic crop reports provide estimates of acreages that farmers intend to plant in a coming season, the acres planted and harvested, the final production and disposition of the crop, and remaining stocks. Forecasts of yields for major crops are issued monthly during the growing season.

The two main elements in determining the prospective size of the crop are relatively straightforward; acreage and average yield per acre. Acreage times yield, minus harvesting and distribution losses, equals the crop. All estimates programs attempt to calculate these two main elements for each crop cycle as accurately and as promptly as dollars and personnel allow. The SRS data collection and analysis methods are comprehensive, long-standing, and thoroughly documented.

Information is collected in many ways: mail surveys, telephone contacts, personal interviews, and in-the-field observations. Augmentation of these methods with remote sensing data is in pilot program stages.

For the most part, SRS bases its estimates on sample surveys. Sampling is less costly in time and money than a co mplete count, and can be more reliable.

Mail Surveys

In most mail surveys, questionnaires are sent to a general purpose sample of farmers as a means of collecting information for an array of agricultural activities: acreges, yield and production, live-stock and poultry inventories, intentions to produce, farm employment and wages.

Probability Surveys

To overcome the shortcomings of general mail surveys, SRS developed and implemented probability surveys in much of its work. Statistical theory provides the basis for selecting samples so that the change, or probability, of each farm or farmer being in the sample can be computed. This offers three definite advantages:

- First, since sampling errors can be determined, estimates can be made with a known degree of precision.
- Second, since the probability sample assures a cross section of U.S. farms, the estimates are not biased as they may be when the sample is not representative as in the older mail surveys.
- Third, the results of the survey stand alone and do not depend upon relationships to any other set of data, such as a census.

SRS probability surveys generally are based on contacts with farmers with land in areas selected for sampling - an area frame. Or based on a sample from a list of producers - a list frame.

- The area frame portion of USDA's probability surveys uses a sample of randomly selected land segments, varying in size but averaging about one square mile in major agricultural areas. In most states, the area frame is stratified for sampling purposes into four broad categories: areas intensively cultivated for

crops; extensive areas used for grazing and livestock; residential and business land in cities and towns; and non-agricultural land. Segments are defined within each stratum, and a sample is selected.

- The chief advantages of the land area frame are that it provides <u>complete</u> coverage, is not made obsolete by changes in farm boundaries or operators, and offers safeguards against omission and duplication.

- An additional sample source is needed, however, for surveys in which the commodity to be estimated is highly concentrated, such as cattle, hogs, poultry, rice, or potatoes. Estimates of these demand more precision than is available from an area sample, and SRS maintains list frames consisting of names and addresses of producers and the size of their units, which are sampled for survey purposes. The lists are kept current by checking names against census data, assessors' files, associations, other USDA lists, and other sources.

- SRS frequently takes advantage of the attributes of the area and list frame samples together, a technique called multiple frame sampling.

<u>Nationwide Enumerative Surveys</u>

Each June and December, SRS conducts a major survey based on samples selected from area and list frames. The farmers are visited by SRS field interviewers--enumerators--for a firsthand accounting of agricultural activities.

The June Enumerative Survey (JES) is conducted during a two-week period, and collects data on crop acreages, livestock numbers, farm labor and wages and produces State, regional, and national estimates.

The December Enumerative Survey covers a subsample of the farms visited in June to provide data for estimates of livestock inventories and production, and acres seeded to fall grain crops.

The probability sample of June includes about 16,000 area segments--roughly 0.7 of 1 percent of the total land area in 48 contiguous States--and will turn up some 60,000 farm operators for interviews. Enumerators also will contact approximately 17,000 extremely large livestock farms.

A typical Corn Belt State will have a sample of about 324 segments. The Southern States with their diversified agriculture will average 425 segments. Texas and California have 850 and 1,000 segments, respectively.

Enumerators, working out of State offices, use county road maps and aerial photographs to define precisely the boundaries of the selected area segments. After locating the appropriate farmers, the enumerators explains the purpose and importance of the survey and asks a specific series of questions. All survey answers by the operators are carefully recorded. The completed questionnaires are sent to the SRS field offices where they are checked for completeness and consistency for use in making the estimates.

A number of quality controls maintain the integrity of the survey: careful selection and training of the 1,500 part-time enumerators, detailed instruction manuals, close field supervision, built-in questionnaire checks, comparison of reported acreages with acreages measured on the aerial photographs, and reeumeration of some segments by supervisors.

Sampling errors for major agricultural items from the June Survey average about 4 to 8 percent on a State basis, about 2 to 3 percent on a regional level, and about 1 to 2 percent for U.S. totals. A sampling error of 1 percent means that chances are about 2 out of 3 that the sample estimate is within 1 percent of the result that would be obtained if the same procedure were used to survey the entire population rather than just a sample of it.

Objective Yield Surveys

Thousands of fields located in the 16,000 segments selected for the June Enumerative Survey are visited during the growing season for plant counts and measurements and crop development information to determine yields and to project production.

Enumerators, with the farmer's permission, walk a given number of rows and paces into the selected fields and mark off a sample unit, no matter what the condition of the field or quality of the crop at the unit. This practice assures objectivity by removing the human bias that could affect the ultimate estimate. These objective yield surveys are conducted mainly for corn, wheat, cotton, soybeans, and potatoes.

In a recent year, sample plots were located in 3,400 corn fields in 20 major producicng States, 2,500 cotton fields in 14 states, over 1,600 soybean fields in 14 States, nearly 1,900 winter wheat fields in 15 States, and 2,100 potato fields in 12 States.

At the designated units in the field, the enumerator counts the number of plants and measures the distance between rows (plant population), and determines the stage of development for a gauge to yield per plant.

With the data on plant population per acre and projected yield per plant, statisticians can arrive at an estimate of yield per acre. They multiply this by the acres for harvest in the State for State production forecasts.

The enumerator repeats his visits monthly during the growing season. When the crop is mature, he hand harvests the sample unit and sends some of it to an SRS laboratory for analysis. After the farmer harvests the field, the enumerator makes a final visit to glean a small section to help indicate harvesting loss and arrive at a net yield estimate.

Crops

The annual cycle of crop estimates begins with reports of farmers' planting intentions, followed by an estimate of acreage actually planted, yield and production forecasts during the growing season, and ends with estimates of harvested acreage, production, and disposition of the crop.

Acreage surveys cover three important periods during the crop production year. The first surveys are for January 1 and April 1 to determine acreage farmers intend to plant in the coming season, based on main responses of more than 100,000 farmers. Acreages actually planted may differ from intentions because of changes in weather conditions, Government programs, or the influence of the report itself.

The second major survey period is early June when most crops are in the ground, with estimate based on information from the June Enumerative Survey and responses from questionnaires mailied to farmers. The acreage estimates are the basis used to compute production August through November.

In some years, weather or other conditions may cause acreage losses or force growers to alter their late planting and utilization plans. An acreage survey is conducted each July to update acreage estimates based on the early June surveys. the first update data appear in the August Crop Production report.

Ideally, new acreage surveys should be carried out when changing conditions develop, but such surveys are expensive and cannot be conducted without considerable preparation. The same conditions limit special crop production surveys between regularly scheduled surveys.

The third acreage survey effort is in the fall to measure acres actually harvested.

Early in the crop season, farmers are asked by mail questionnaire to evaluate their crop in terms of its present condition in relation to a normal conditions, taking into account seasonal progress, weather, insects, fertilizer use, and other cultural practices. The aggregate of these indications for a State is then evaluated in relation to h istoric yields and reported by SRS.

During the growing season, SRS relies heavily on information from the objective yield surveys, supplemented by farmers' mail responses about prospects, to indicate yields of corn, cotton, wheat, and soybeans. For other crops, the judgement of the producer provides the major yield data.

These indications are translated into State, regional, and national forecasts by means of regression charts on which probable yields are plotted against final yields over a series of years.

SRS revises its estimate periodically, not as a matter of correcting history, but to provide a better base for current and future estimates. Revisions are made annually for products for which sufficient check data

are available. When check data for a crop become available after harvest, the official estimates of output may be revised.

There are many incentives throughout the crop reporting process to have it work accurately and effectively. The farmers, processors, distributors, etc., all need accurate and timely data for the thousands of individual decisions made in whole or in part of the basis of crop reporting at the county, state, national and international level.

USDA methods for crop production reporting, as described above, are so long-standing and statistically rigorous, that enhancements via remote sensing techniques are necessarily limited, and have been handled very carefully to assure that the remote sensing enhancements can be coupled to the conventionally derived data. The objectives have been the same as with the conventional techniques; namely, to attempt to find objective, repeatable improvements that are cost effective and can be sustained as routine parts of the reporting process.

The SRS approached the use of Landsat on a pilot project basis, beginning at the state level with Iowa, which is perhaps the most homogeneous state because of the extent and type crops. In 1978 the detailed "ground truth" from the roughly 300 ground survey segments (one-mile x one-mile) in Iowa were used to "train" a computerized classification of the millions of pixels contained in some 12 Landsat scenes covering Iowa that were acquired at the height of the growing season (August to early September). The resulting data were used to reduce the estimate error embodied in the conventional data. At the state level, the additional accuracy of crop acreage estimate was such that two and one-half times as much ground survey would have been needed to equal the accuracy results obtained by using the original ground survey data, enhanced by the results of the Landsat analysis. The 1978 effort was slow, complicated, and aimed at demonstrating that computer processing of properly registered Landsat imagery, "trained" by ground survey data, could yield useful results. This work, and other similar and follow-up investigations has been published. An extensive body of technical literature exists. The analytical effort has been carried forward in the Remote Sensing Branch of SRS, with refinements of techniques and extension to cover an increasing number of states.

Details on the status of the work in USDA and the NASA-USDA interaction through AgRISTARS are too extensive for presentation here, and the limited account in the foregoing section do not do justice to the scope of the USDA and NASA activities. The major point is to recognize the complementary role of remote sensing techniques to the conventional techniques, and the importance of continuing interaction between NASA and USDA activities. Many of the relationships and problems described in the body of the Report apply to agricultural reporting.

With respect to remote sensing and the user requirements, the R&D role of NASA and the operational role of USDA continue to represent a dichotomy. NASA continues to be characterized as having "technical answers looking for user applications," while USDA is characterized as performing legislated functions of the kind described above that have their own conventional data sources and complex histories. The incentive from the NASA standpoint is to perform space-oriented technical research as broadly as possible, while for USDA the incentive is to develop even modest improvements on an already effective system. It is difficult to say what type of improvement (timeliness, accuracy, breadth, etc.) would be the most important to try to achieve via remote sensing in the domestic crop production reporting. The SRS approach is to attempt improvements on all fronts, and combine its remote sensing work with many parallel activities within USDA. These include many types of applications beyond crop reporting, *per se*: land cover classification, forest and crop inventories of various types, soil erosion, disaster relief programs. etc.

Remote sensing techniques are widely used in USDA including air-borne collection to support individual programs. Geographically-based information is accepted as a necessity. The issues are generally over what specific quality or quantity are needed, and the methods to employ. Remote sensing was likened to the era of key-punching with computers. It is simply recognized that much more advanced techniques will become technically and economically feasible. The only question is when and how the long range transition can be made effectively.